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# LAKE OKEECHOBEE REGULATION SCHEDULE STUDY

## Socio-Economics Final Report - Appendix D
## Wildlife Survey and Habitat Utilization Study of Western Littoral Zone, Lake Okeechobee, Florida - Appendix E
## Draft Fish and Wildlife Coordination Act Report - Annex A
## Coastal Zone Consistency Evaluation - Annex B

*June 1999*

# APPENDIX D

# SOCIO-ECONOMICS FINAL REPORT

# FINAL REPORT

## ECONOMIC IMPACT EVALUATION

## LAKE OKEECHOBEE REGULATION SCHEDULE STUDY

**Prepared by :**
**David Miller & Associates, Inc.**

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## Acronyms

| | |
|---|---|
| AFSIRS | Agricultural Field Scale Irrigation Requirement Simulation |
| ASR | Aquifer Storage and Recovery |
| C&SF | Central and Southern Florida |
| CFS | Cubic Feet per Second |
| COEREC | An alternative Lake Okeechobee Regulation System |
| EAA | Everglades Agricultural Area |
| EPP | Economic Post-Processor |
| ET | Evapotranspiration |
| FASS | Florida Agricultural Statistics Service |
| HSMREC | An alternative Lake Okeechobee Regulation System |
| HSP | Hydrologic Simulation Program |
| IFAS | Institute for Food and Agricultural Science, Univ. of Florida |
| I-O | Input-Output |
| LCA | Least Cost Alternative |
| LEC | Lower East Coast |
| LORSS | Lake Okeechobee Regulation Schedule Study |
| LOSA | Lake Okeechobee Service Area |
| LOTAC | Lake Okeechobee Technical Advisory Committee |
| LPMS | Lock Performance Monitoring System |
| LV | Low volume irrigation |
| M&I | Municipal and Industrial |
| NED | National Economic Development |
| NEPA | National Environmental Policy Act |
| NGVD | National Geodetic Vertical Datum |
| NRCS | Natural Resources Conservation Service |
| NRMS | Natural Resources Management System |
| OS | Operating Schedule |
| OV | Overhead irrigation |
| PET | Potential Evapotranspiration |
| PPM | Parts per Million |
| RED | Regional Economic Development |
| RM | River Mile |
| RUN22AZE | An alternative Lake Okeechobee Regulation System |
| Run25 | The current Lake Okeechobee Regulation System |
| SA | Service Area |
| SCORP | Statewide Comprehensive Outdoor Recreation Plan |
| SFWMD | South Florida Water Management District |
| SFWMM | South Florida Water Management Model |
| SSM | Supply-side management |
| USDA | U.S. Department of Agriculture |
| WCA | Water Conservation Area |
| WTP | Willingness to Pay |

# EXECUTIVE SUMMARY

Lake Okeechobee is the heart of the south Florida water management system. Its waters are used to maintain the Everglades ecosystem, irrigate agriculture, and meet the growing municipal and industrial water demands of the urbanized Lower East Coast (LEC). The U.S. Army Corps of Engineers (Corps) is conducting the Lake Okeechobee Regulation Schedule Study (LORSS) to evaluate the feasibility of modifying the lake's regulation schedule. The purpose of the study is to formulate a lake regulation schedule that will promote the ecological health of the lake's littoral zone while maintaining the authorized project purposes of flood protection and water supply. The South Florida Water Management District (SFWMD) is the non-Federal sponsor of the LORSS project and has conducted most of the hydrologic analysis upon which this estimate of economic impacts is based.

This investigation examines the economic consequences of the four LORSS alternative regulation schedules, known as Run22AZE, COEREC, HSMREC, and WSE. The effects have been estimated by comparing the with- and without-project conditions (present and future). The without-project condition is the current regulation schedule, known as Run25.

The alternative schedules were designed to manage high lake levels and thereby protect the integrity of the lake's levee system which provides flood protection for lakeside communities. Each regulation schedule stipulates the timing, magnitude, duration, and outlets for the regulatory (i.e., high-water) releases from the lake. However, by controlling high lake levels and the lake's water storage, the alternative regulation schedules affect the frequency and duration of all lake stages.

The economic evaluation focuses on impacts of regulatory releases and consequent lake level fluctuations on agricultural and urban water supply, recreation, navigation, and commercial fishing. The SFWMD's South Florida Water Management Model (SFWMM) is the principal tool for evaluating the alternative regulation schedules. This model, which simulates the hydrology and water management of south Florida, generates two sets of simulations (1990 and 2010), which are used in this analysis as proxies for existing and future study area conditions.

## AGRICULTURAL WATER SUPPLY

As described in Chapter 2, the management of Lake Okeechobee has significant implications for water supply to south Florida agriculture, which has an annual output worth approximately $3.8 billion. Agriculture in the Lake Okeechobee Service Area, particularly the Everglades Agricultural Area (EAA), is dependent on releases from Lake Okeechobee for crop irrigation. During periods of normal rainfall, agricultural water users in the LEC do not require supplemental releases from the lake. However, during prolonged droughts, significant volumes of water from Lake Okeechobee can be required in the LEC to supplement local water supplies and to prevent saltwater intrusion into coastal aquifers. Agriculture in the EAA is dominated by sugar cane. Agriculture in the LEC is more diverse, with row crops (i.e., truck vegetables) as the predominant crop type.

The potential effects of the alternative regulation schedules on agricultural water supply are based on the magnitude and frequency of irrigation water shortages. If crops do not receive sufficient moisture from precipitation or irrigation, crop transpiration is reduced, and growth rates can be affected. Reduced growth rates result in lower crop yields and, ultimately, lower farm income. The economic effects of the alternative regulation schedules are the differences between expected farm income under the with- and without-project conditions.

The SFWMD developed an economic post-processor (EPP) to assess the economic effects of agricultural water supply shortages. The EPP, which is embedded in the SFWMM, was designed to estimate the agricultural water supply impacts of physical or operational changes in south Florida's water management system. As part of this investigation, the SFWMM and EPP were used to estimate the National Economic Development (NED) effects of the LORSS alternatives on agricultural water supply.

The NED account includes the net farm income effects associated with changes in revenues or production costs resulting from plan implementation. Because production costs are not expected to change between the without- and with-project conditions for the LORSS, changes in net income are equivalent to changes in net revenue.

Table ES-1 summarizes the average annual NED effects of the alternative regulation schedules (relative to the current regulation schedule) under anticipated 2010 conditions. The first row of this table presents the NED effects of the four alternative schedules on agricultural water supply estimated as the differences between the values for unmet demand for irrigation water under the with- and without-project conditions. Under the current regulation schedule (Run25) and alternative regulation schedules, farmers are not expected to receive all of the irrigation water they desire all of the time. The first row of Table ES-1 illustrates the differences between Run25 and the alternative regulation schedules in terms of agricultural water supply. The values in the first row of this table represent simulated income losses from agricultural water supply shortages during the SFWMM's 31-year simulation period. Negative numbers in this table indicate that the alternatives have unmet agricultural water demands that exceed those associated with the current regulation schedule (i.e., result in worsened conditions).

The Caloosahatchee River and the St. Lucie Canal serve as major outlets for Lake Okeechobee, connecting the lake to the Gulf of Mexico and the Atlantic Ocean, respectively. The EPP does not address agricultural water supply effects in these basins, since they are not included in the SFWMM's grid system. However, the SFWMM does simulate the agricultural demands not met for these basins under with- and without-project conditions (present and future). Under simulated 2010 conditions, the without-project conditions (Run25) are expected to have 17% of agricultural water demands not met in these two basins, and the alternative regulation schedules are anticipated to have the following percentages (%) of agricultural demands not met: Run22AZE (21%), COEREC (18%), HSMREC (14%), and WSE (17%).

**TABLE ES-1**
**ESTIMATED AVERAGE ANNUAL ECONOMIC EFFECTS OF ALTERNATIVE REGULATION SCHEDULES RELATIVE TO THE CURRENT REGULATION SCHEDULE (RUN25) UNDER SIMULATED 2010 CONDITIONS ($1996)**

| Economic Activities | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|
| Agricultural Water Supply: EAA and LEC | -$1,294,597 | -$507,761 | +$635,038 | +$187,931 |
| Municipal and Industrial Water Supply | -$1,232,063 | -$681,324 | +$803,373 | -$530,757 |
| Commercial Navigation* | -$46,226 | Neutral | +$23,113 | -$23,113 |
| Recreation* | -$435,173 | Neutral | +$217,586 | -$217,586 |
| Commercial Fishing* | No economic effects anticipated with alternative schedules. | | | |
| **TOTAL** | **-$3,055,875** | **-$1,189,085** | **+$1,703,018** | **-$583,525** |

*These values were generated through illustrative examples and worst-case scenarios.

## MUNICIPAL AND INDUSTRIAL WATER SUPPLY

As discussed in Chapter 3, the LORSS alternative regulation schedules could potentially result in changes in the frequency, severity, duration, and location of municipal and industrial (M&I) water supply shortages. In the LORSS study area, most M&I water use is in the LEC. If water demands exceed supplies, shortages will result, and cutbacks may be imposed by the SFWMD. The SFWMD's Water Shortage Plan curtails water use in south Florida using a four-phase progression of more severe restrictions: Phase I (Moderate), Phase II (Severe), Phase III (Extreme), and Phase IV (Critical).

The phased restrictions on M&I water use during shortages have associated costs. There may be direct economic costs associated with active conservation measures, particularly for residential and commercial water users, who could experience increased costs or decreased satisfaction as a result of supply restrictions on water-related activities (e.g., watering lawns, washing cars). If shortages are frequent, there may also be economic impacts in the form of costs associated with developing new, more reliable sources of supply.

The conceptual basis for evaluating the economic effects of changes in M&I water supply associated with alternative plans is society's willingness to pay (WTP) for the increase in the value of goods and services attributable to the water supplied. The Corps of Engineers traditionally uses the Least Cost Alternative (LCA) method to estimate economic effects on M&I water supply. However, WTP was selected as the primary approach to evaluate the M&I water supply impacts for the LORSS for two principal reasons. First, most of the M&I systems in the study area are connected to the regional water system, greatly complicating the LCA approach. Second, the EPP already contains a WTP measure for estimating M&I water supply effects of the alternative regulation schedules.

Table ES-1 presents the economic value of unmet demand for M&I water supply for the four alternative schedules. The values in this table represent the dollar amounts that M&I water users are willing to pay for water they want but do not receive during water shortages. Negative values indicate that the alternative regulation schedule has greater unmet M&I water demands than the current regulation schedule (i.e. results in worsened conditions).

## COMMERCIAL NAVIGATION

The alternative regulation schedules are expected to alter average lake stages on the Lake Okeechobee Waterway, which consists of the lake, the Caloosahatchee River, and the St. Lucie Canal. However, as examined in Chapter 4, the impact of the regulation schedules on the frequency of extremely low lake levels (i.e., less than 13 feet NGVD) is likely to be more important for commercial navigation than the change in average lake levels. If some portion of the commercial vessel fleet draws all of authorized depth, reduced waterway stages could prevent passage of those vessels, delay their passage, or induce reductions in their average loads.

The Lake Okeechobee Waterway was completed in 1937 and includes 154 miles of navigation channel and five lock structures linking Stuart on the Atlantic Ocean with Ft. Myers on the Gulf of Mexico. There are five lock and dams (from west to east): W.P. Franklin, Ortona, and Moore Haven on the Caloosahatchee River and Port Mayaca and St. Lucie on the St. Lucie Canal. The Moore Haven and Port Mayaca locks connect the lake with the Caloosahatchee River and St. Lucie Canal, respectively. There are two routes from Port Mayaca on the lake's eastern shore to Clewiston on the southwestern shore. Route 1, which cuts across the lake, has a deeper channel (8 feet). Route 2, which hugs the eastern shoreline, is known as the rim canal. This route has a shallower channel (6 feet) and is longer than Route 1, but it is more sheltered from the severe wave conditions that the shallow depths of the lake frequently engender. The channel depths of 8 feet and 6 feet for the lake and rim channel, respectively, are measured relative to an average lake elevation of 12.56 feet NGVD. Management of lake levels is used to maintain authorized channel depths – no dredging is performed. Therefore, for periods in which lake levels fall below 12.56 feet NGVD, the navigable depth in the lake and rim channels decrease by an equivalent amount. So, for example, if lake levels fall to 11 feet NGVD, the navigable depths in the lake and rim channels would be approximately 6.5 and 4.5 feet, respectively.

Commercial navigation on this waterway has been stable over the past ten years, with substantial year-to-year variation. The Lake Okeechobee Waterway was used to transport 430,000 tons of freight in 1995. Petroleum products were the predominant commodities transported. The number of tows passing through the five locks ranged from 97 to 226 in 1996. The average number of barges per tow ranged from 1.1 to 1.5.

There are no commercial shipping lines which maintain regular service through the Lake Okeechobee waterway. As a result, there is no dedicated fleet of commercial waterway users, and there is no regularly scheduled routing of commodity shipments through the waterway. The commercial traffic consists of special barge shipments that take advantage of the shortcut across the peninsula, which can save 3 to 5 days of travel. In some cases, deep-draft tugs transfer their tows to shallow-draft tugs for passage through the Lake Okeechobee Waterway.

Based upon field research and database searches regarding commercial navigation on the Lake Okeechobee Waterway, it can be concluded that the effects of the alternative regulation schedules on commercial navigation through the Lake Okeechobee Waterway would be very small. Table ES-1 presents the results of an extreme, "worse case" scenario that was conducted to quantify the likely upper boundary of impacts on commercial navigation which could occur if lake stages fell below 11 feet NGVD. While the values are based upon a series of simplifying assumptions, they indicate that the effects of changes in regulation schedules on commercial navigation are minimal.

In addition, the infrequent and irregular nature of navigation on the waterway raises the question of whether shipments through the waterway could be deferred until lake levels increase, with little ill effect. Revisions in lock management practices during drought conditions, as suggested by the lock masters, could also reduce the impacts of the alternative regulation schedules on commercial traffic. Finally, the combination of the minor difference in the frequency of extreme low lake levels between the alternative schedules and relatively light and irregular commercial traffic on the waterway supports the conclusion that the impacts of the alternative regulation schedules on commercial navigation will be negligible.

There are several other related commercial navigation issues that are directly or indirectly affected by changes in lake levels. There is an increased probability of vessel groundings when lake levels are low. Low lake levels will also likely require additional costs to relocate and/or install new aids to navigation. The management plan for whichever alternative regulation schedule is selected should include operational strategies to minimize these potential negative effects.

## RECREATION

Lake Okeechobee is the largest recreational resource in the region. The lake and its associated waterways and shoreline provide a wide variety of water-based recreation activities for local residents and out-of-state visitors, including: fishing, boating, picnicking, sightseeing, camping, swimming, hunting, airboating, and hiking. The western side of the lake is relatively shallow, with an extensive littoral zone. This area provides critical habitat for the lake's popular sportfishery. It also attracts thousands of waterfowl, which lure hunters during the fall migration. In addition, Lake Okeechobee is recognized as supporting one of the best recreational fisheries in the nation.

As explored in Chapter 5, the economic effects of the alternative regulation schedules on recreation are estimated by quantifying the differences in both the quantity and quality of recreation activities expected to occur under with- and without-project conditions. In 1996, recreation levels at Lake Okeechobee were estimated at 64,503,500 visitor-hours. Using the Unit Day Value method, the annual value of the recreational resource is estimated at $78,151,409.

The quantity and quality of recreation on Lake Okeechobee are sensitive to fluctuations in lake levels. There are three categories of impacts of lake level fluctuations on recreation on Lake Okeechobee. First, lake levels can impact recreational access to the lake by affecting use of boat ramps. Based on a survey of boat ramps conducted for this investigation, it appears that use of some boat ramps on the lake would be precluded by extremely low lake levels.

Second, lake levels determine where boaters and fishermen can go on the lake. Since the lake's littoral zone occupies approximately 25% of the lake area, access to much of the lake is sensitive to lake level fluctuations.

Finally, the quality of recreation – particularly sportfishing – on Lake Okeechobee can also be affected by fluctuations in lake levels. The ecology of Lake Okeechobee evolved under conditions where lake levels fluctuated seasonally. The degrees to which the alternative regulation schedules mimic natural stage fluctuations have implications for the health of the fishery. The effects of lake stages on the ecology of the lake are complex. Low lake stages: (1) allow muck to consolidate on the exposed lakebed thereby improving water quality and benthic habitat, (2) permit emergent vegetation to extend further into the lake, cleansing the water column, and (3) enable controlled burning of exotic (i.e., non-native) species. However, low lake stages can also kill desirable, native aquatic vegetation. Similarly, high lake stages also have mixed effects on the sportfishery, since they kill undesirable exotic vegetation but also adversely impact desirable aquatic vegetation.

The ecological effects of changes in lake stages must be evaluated from both the short-term and long-term perspectives. For example, recreational fishing may suffer in the short term when lake stages are low, since the water is warmer and many gamefish are forced from shallow to deep water. However, longer term benefits to fishing from the drawdown can be realized the following year as fish stocks increase due to habitat improvements. Similarly, high lake stages may increase fishing in the short term by allowing better access to the lake, but the inundation of the littoral zone may have adverse effects on fishing the following year as a result of its diminished function as a fish nursery.

There are also the short-term considerations regarding whether the fish are "biting". Local fishermen report that the quality of the fishing declines significantly when lake levels get low, water temperatures rise, and dissolved oxygen levels fall. Discussions with sportfishermen on Lake Okeechobee yielded a variety of opinions regarding the critical threshold when lake levels begin to affect the quality of fishing. In general, this threshold was reported to be approximately 14 feet NGVD.

In general, the quantity and quality of recreation on Lake Okeechobee is reduced as lake levels fall below 13 feet NGVD. Table ES-1 presents the results of a scenario which uses a series of simplifying assumptions to illustrate the sensitivity of recreation to changes in lake levels associated with the LORSS alternatives. The scenario evaluates the reduction in recreation quality associated with very low lake levels (i.e., less than 11 feet NGVD). As evident in this table, the impacts of the alternative plans are insignificant with respect to the total value of recreation on the waterway. It may be the case, however, that the majority of recreation impacts would occur from more frequent, less severe, low lake level conditions. For example, the frequency of lake levels below 13 feet for more than 100 days would no doubt be greater than the frequency of events below 11 feet, and these less severe events could also impact the quantity and/or quality of recreation on Lake Okeechobee.

## COMMERCIAL FISHING

As discussed in Chapter 6, Lake Okeechobee is home to an active commercial fishing industry. This includes several different types of commercial fishing operations and landside support activities, such as marinas and fish houses, which purchase the catch for wholesale and retail distribution. The commercial catch in Lake Okeechobee includes: catfish and bream (bluegill and redear sunfish).

The NED account registers changes in net income from commercial fishing operations. Net income changes result from either changes in the size of the catch (net revenues) and/or changes in the cost of catching the fish (net operating costs). The LORSS alternative regulation schedules are not anticipated to affect the overall size of the Lake Okeechobee fishery or the amount of the commercial fishing catch. Although net fishing revenues are not expected to be affected, the cost of commercial fishing operations could potentially be impacted by changes in the lake's regulation schedule. The single greatest determinant in the size of the fishing catch (and net fishery revenues) are the complex series of operational restrictions placed on the fishery by state fisheries management agencies.

There are three types of gear used by commercial fishermen on Lake Okeechobee: haul seine, trotlines, and wire traps. Haul seines are responsible for two-thirds of the 6 million pounds of annual commercial harvest from the lake. The haul seiners prefer lake levels that are in the 13 to 14 foot NGVD range. Lower lake levels constrain their movements around the lake. Deeper water makes using their gear more difficult to use, and fish will move into shallow waters that are inaccessible to commercial fishermen. Also, the commercial fishermen recognize that very high or very low lake levels inundate or drain the lake's littoral zone which is critical to fish spawning.

Regarding the other types of commercial fishing, the fishermen who use trotlines and wire traps generally prefer deeper waters in the lake, since they both generally fish for catfish. According to state fisheries biologists, there are only a few fishermen who use wire traps, and they are required by regulation to have to five feet of water over the traps. They generally prefer water depths around 8 feet. The trotline fishermen also seem to prefer relatively deep water in the lake.

In general, commercial fishing operations on Lake Okeechobee are not very sensitive to changes in lake levels. The drafts of the commercial fishing vessels are sufficiently shallow to allow access to Lake Okeechobee throughout the range of lake levels anticipated with the alternative regulation schedules. While the fishermen seem to prefer lake levels in the intermediate range, they would rather have lower lake levels than higher lake levels. As indicated in Table ES-1, no significant differences between with- and without-project conditions are expected under the 1990 (present) and 2010 (future) scenarios.

## EFFECTS OF LAKE RELEASES ON ST. LUCIE & CALOOSAHATCHEE ESTUARIES

As described in Chapter 7, the quantity, quality, and timing of Lake Okeechobee releases to the St. Lucie and Caloosahatchee estuaries are critical determinants of the diversity and productivity of these ecosystems. The conditions of the ecosystems, in turn, have economic implications for commercial and recreational fishing. Although it was not possible to quantify the anticipated economic effects of the alternative regulation schedules on the economics of these fisheries, the SFWMM simulates hydrologic information that can be interpreted from an economic perspective. In general, the alternative regulation schedules are expected to comprise improvements over the without-project present and future conditions. Specifically, the alternative schedules are anticipated to reduce the number of regulatory (i.e., high-water) releases to the estuaries. This suggests that alternative schedules could result in improvements in the economics of commercial and recreational fishing relative to present and future conditions under Run25. However, the alternative schedules will not meet the SFWMD's salinity-based goals for high-water releases to these estuaries.

## REGIONAL ECONOMIC EFFECTS

The effects of the alternative regulation schedules on the Regional Economic Development (RED) account were estimated using a regional input-output model, *IMPLAN*. The NED effects of the alternative schedules (see Table ES-1) were input to the model to estimate changes in regional industrial output, employment, and income. Not all of the NED effects could be analyzed in the input-output model. For example, as explained in Chapter 8, the M&I water supply impacts of the alternative schedules could not be evaluated in the regional model. The results of the RED analysis suggest that the regional economic effects of the alternative regulation schedules would be inconsequential (i.e., less than .000003% of annual industry output) for the regional economy, which is estimated to have a 1996 industrial output of $231.2 billion.

# 1. INTRODUCTION

## BACKGROUND

Lake Okeechobee is a large, freshwater lake located in central Florida. The lake is regulated for flood control and water supply purposes and is the heart of south Florida's water management system. During the wet season, lake levels are regulated to reduce potential flood damages by storing enormous volumes of water. During the dry season, stored water is released to support the Everglades ecosystem and to provide water supply to south Florida's municipal and industrial users and irrigated agriculture.

Lake levels are actively managed during high and low water conditions. The principal purpose of the lake regulation schedule is to control high water conditions. The potential for heavy rains and severe tropical storms in south Florida requires that the lake be carefully monitored to ensure that water levels do not threaten the structural integrity of the levee system surrounding the lake. When water levels in the lake reach certain elevations designated by the operating schedule, regulatory releases are made through the major outlets to control excessive buildup of water in the lake. The principal outlets are the Caloosahatchee River, which flows westward to Ft. Myers and the Gulf of Mexico; and the St. Lucie Canal, which extends eastward to Stuart and the Atlantic Ocean. Conversely, when lake water levels are excessively low, such as during droughts, the lake undergoes supply-side management, and releases are restricted to conserve stored water. The outcome of these management measures has been fluctuations in lake levels that are roughly twice the range of historical conditions.

In recent years, three categories of environmental concerns have arisen regarding the operation of the lake. First, extended periods of high lake levels stress the lake's littoral zone, which provides important fish and wildlife habitat. Second, insufficient water releases from the lake to the Everglades have contributed to the deterioration of the Everglades ecosystems. Third, high-water (regulatory) releases from the lake have contributed to ecological deterioration in the Caloosahatchee and St. Lucie estuaries through salinity effects on these sensitive ecosystems.

The U.S. Army Corps of Engineers (Corps) is conducting the Lake Okeechobee Regulation Schedule Study (LORSS) to evaluate the feasibility of modifying the lake's regulation schedule. The purpose of the LORSS is to attempt to formulate alternative lake regulation schedules that will reverse ecological damages while continuing to meet flood damage reduction and water supply needs. The LORSS is being conducted in cooperation with the South Florida Water Management District (SFWMD), the non-Federal sponsor.

In addition to the environmental, flood damage reduction, and urban and agricultural water supply parameters, there are other considerations that enter into decision making regarding management of the lake. These considerations include: (1) commercial navigation across the Florida peninsula via the Lake Okeechobee Waterway, which includes the lake, the Caloosahatchee River, and the St. Lucie Canal, (2) the lake's extensive recreational resources, which include a very popular sportfishery, and (3) commercial fishing on the lake. In addition, there is public concern that releases of fresh water to the Atlantic Ocean and the Gulf of Mexico are a waste of scarce water resources in a state with increasing water shortages.

## 1.1 PURPOSE OF THIS INVESTIGATION

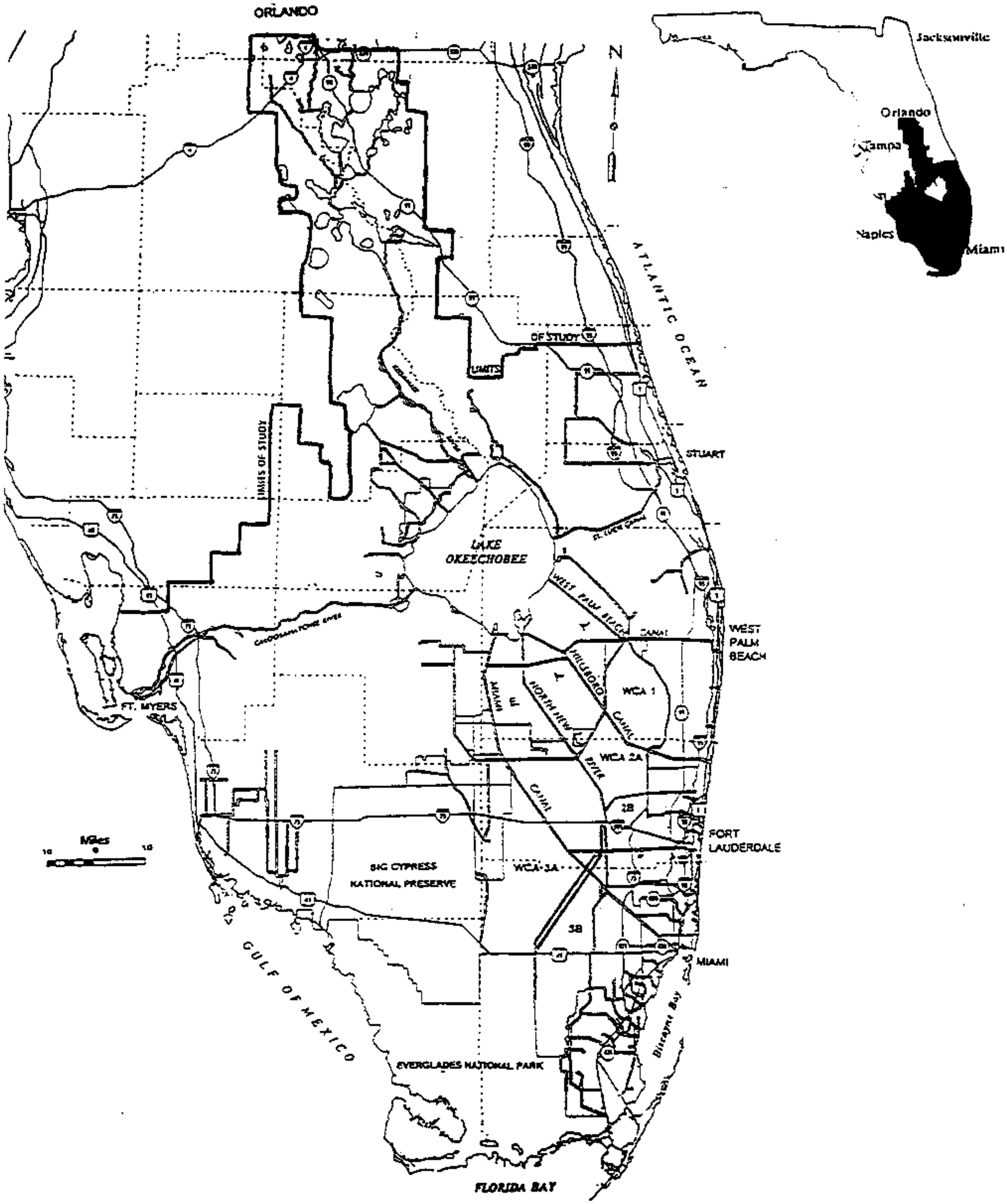
This investigation explores the economic consequences of the four LORSS alternative regulation schedules (i.e., lake management plans) and the current regulation schedule. This economic evaluation will focus on agricultural and urban water supply, recreation, navigation, and commercial fishing. Specifically, the differences between the with- and without-project future conditions will be estimated to anticipate the effects of the alternative regulation schedules. Economic effects will be presented in terms of both net national effects (National Economic Development or "NED" effects) and regional effects (Regional Economic Development or "RED" effects). The procedures for estimating NED and RED effects are described in the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies (U.S. Water Resources Council, 10 May 1983), ER 1105-2-100, and other Corps planning guidance.

The goal of modifying the regulation schedule is to improve the health of the extensive littoral zone of Lake Okeechobee while maintaining the authorized project purposes of flood damage reduction and water supply. Economic justification of the revised operating schedule is not required. However, the economic impacts of the proposed modification of the current schedule are being estimated to aid Federal decision makers and the non-Federal sponsor in their evaluation of the alternative regulation schedules and selection of the optimal plan.

The LORSS is being conducted in close coordination with the ongoing Central and Southern Florida (C&SF) Comprehensive Review Study. The C&SF project is a system of levees, canals, and water control structures designed to provide flood control, water supply, and other services to south Florida. Lake Okeechobee is a critical element of this system. Although the C&SF project has performed its intended purposes well, it has also contributed to the decline of the south Florida ecosystem. In response to this decline, Congress authorized the C&SF study to investigate structural and operational modifications to improve: (1) the quality of the environment, (2) protection of aquifers, (3) urban and agricultural water supplies, and (4) other water-related purposes.

## 1.2 STUDY AREA

The LORSS study area consists of the 16-county jurisdictional area of the SFWMD (see Figure 1-1). Lake Okeechobee extends approximately 30 miles east to west and 33 miles north to south. It encompasses approximately 730 square miles (427,000 acres) at lake elevation 15.5 feet National Geodetic Vertical Datum (NGVD), making it the second largest freshwater lake within the contiguous United States (following Lake Michigan). Although Lake Okeechobee is shallow (average depth under 10 feet) it holds an enormous amount of water, estimated at 5,106,000 acre-feet at the maximum stage under the current regulation schedule (17.5 feet NGVD). Lake Okeechobee is surrounded by the Herbert Hoover levee system which extends 140 miles with an average elevation of 34 feet NGVD. The effective limit for on water supply withdrawals from the lake is 9.5 feet NGVD due to physical limitations of the outlet structures. At this stage, the




## FIGURE 1-1
## LORSS STUDY AREA

Source: U.S. Army Corps of Engineers. Central and Southern Florida Comprehensive Review Study. Plan of Study. 1997.

lake retains an estimated 1,884,000 acre-feet of water that is considered inaccessible for water supply purposes. As a result, the maximum available water reservoir storage at 17.5 feet NGVD would be 3,222,000 acre-feet.

The principal tributary to Lake Okeechobee is the Kissimmee River, which enters the lake from the north. Other tributaries include: Taylor Creek, Nubbin Slough, Nicodemus Slough, and Fisheating Creek. Water leaves the lake through four principal avenues. First, in the south Florida climate, the lake loses tremendous amounts of water to evaporation, accounting for as much as 70% of all water losses from the lake. Second, during high lake stages, water is released eastward to the Atlantic Ocean via the St. Lucie canal. Similarly, high water releases are also made westward to the Gulf of Mexico via the Caloosahatchee River. Finally, lake water is released southward via a system of water supply structures and canals. Major water supply conduits include: the Miami, North New River, Hillsboro, and West Palm Beach canals. These canals convey water for: (1) agricultural uses in the Everglades Agricultural Area (EAA), (2) agricultural and urban water uses in the eastern portions of Palm Beach, Dade, Broward, and Monroe counties, and (3) the Everglades National Park via the Water Conservation Areas (WCAs) located southeast of Lake Okeechobee.

Since Lake Okeechobee is so critical to water management in south Florida, the study area encompasses the jurisdictional area of the SFWMD, which includes the lake, its tributary basins to the north, and all of south Florida. However, this analysis of the potential economic effects of the alternative regulation schedules will focus on the water supply planning regions depicted in Figure 1-2, since these areas will experience the majority of the economic effects of the alternative regulation schedules. These areas include the Lake Okeechobee Service Area (LOSA) and the Lower East Coast (LEC) of south Florida. These areas are designated by the SFWMD's South Florida Water Management Model (SFWMM). They include the five sub-areas of the LOSA and the three urbanized service areas of the LEC. Referring to the sub-area designations in Figure 1-2, the five LOSA sub-areas consist of: (1) northern Palm Beach County, (2) the EAA which primarily lies within western Palm Beach County but also eastern Hendry County, (3) the northern lake district, (4) the Caloosahatchee river basin, and (5) the St. Lucie basin. The LOSA also includes two Seminole Indian reservations, Brighton and Big Cyprus, which are not shown in Figure 1-2. The three LEC service areas (SA1-SA3) primarily lie within Palm Beach, Broward, and Dade counties, respectively. The water supply of Monroe County (not shown in Figure 1-2) is primarily provided by wellfields in Dade County (SA3).

## 1.3 WITHOUT-PROJECT CONDITIONS

Water levels in Lake Okeechobee are managed through regulatory (flood control) and nonregulatory releases. Regulatory releases are made according to the regulation schedule established by the Corps in conjunction with the SFWMD to ensure that the integrity of the levee system surrounding the lake is not compromised by high water levels (Hall, 1992). The current regulation schedule for Lake Okeechobee is Operation Schedule 25-3 (OS25-3). This regulation schedule, known as Run25, was developed by the SFWMD to improve the balance of competing operational objectives for the lake, relative to the previous regulation schedules. Run25 was implemented in December 1994 as an interim schedule, pending the outcome of the LORSS. It is illustrated in Figure 1-3. The Run25 schedule is intended to maintain: (1) low lake stages

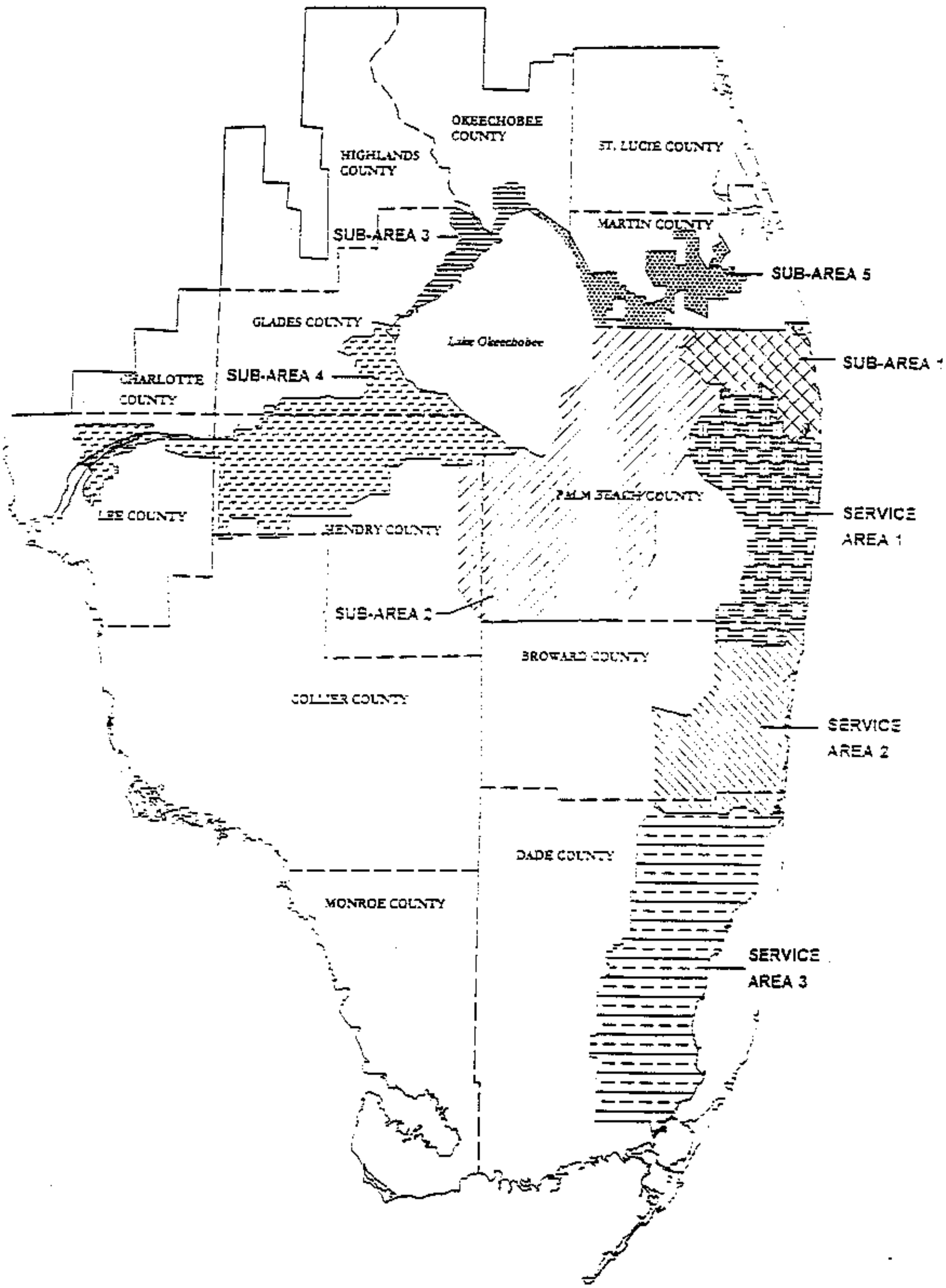



**FIGURE 1-2**
**LOSA AND LEC SERVICE AREAS**

Source: U.S. Army Corps of Engineers. Central and Southern Florida Comprehensive Review Study. Plan of Study. 1997.

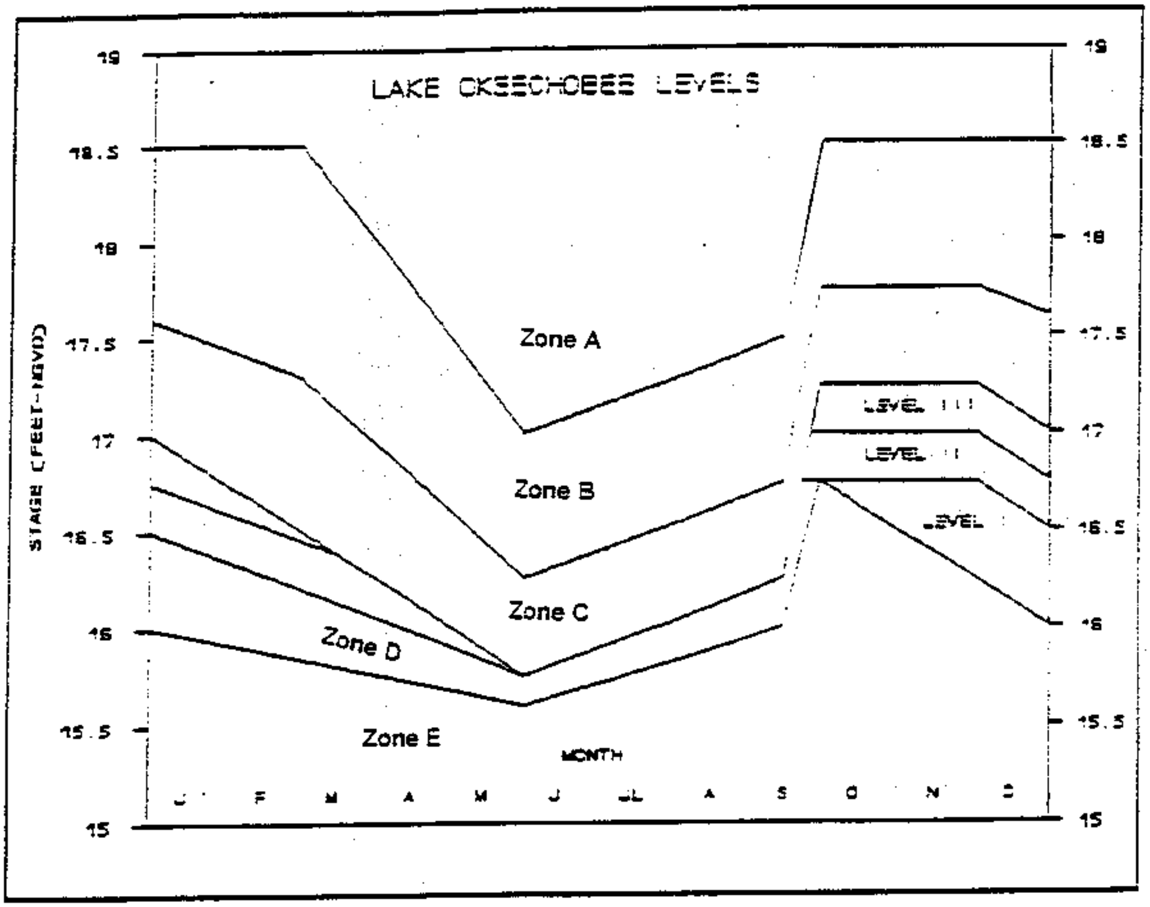



**FIGURE 1-3**
**RUN25 REGULATION SCHEDULE**

Source: Hall, C.A. Guide for the Management of High Lake Stages of Lake Okeechobee. SFWMD. 1992.

during the wet season (i.e., summer months) to preserve storage capacity and (2) high lake stages during the dry season (i.e., winter months) to retain stored water. Consequently, Run25 was designed to achieve the following lake level targets: 15.65 feet NGVD in late May and 16.75 feet NGVD at the beginning of October.

The regulation schedule has management zones which specify outlets and regulatory release rates according to the time of year and prevailing lake stage. As indicated in Figure 1-3, regulatory releases are specified by five different regulation zones (A-E) in accordance with the lake stage (vertical axis) and time of year (horizontal axis).

Nonregulatory releases are made from the lake to meet: (1) environmental water supply requirements of the Everglades ecosystem, (2) water supply requirements of the LEC, (3) agricultural irrigation water demands in the LOSA, and (4) water supply and environmental needs in the St. Lucie and Caloosahatchee estuaries. Nonregulatory releases from the lake to the two estuaries are made in response to particular circumstances throughout the year. In general, releases are made during low flow periods to provide sufficient freshwater inflows into the estuaries to maintain ecologically desirable salinity levels.

Regulatory releases from the lake are directed southward toward the Water Conservation Areas (and the Everglades ecosystem) to the fullest extent possible. When the need for regulatory releases exceeds the receiving capacity of the Water Conservation Areas, releases are made to the two estuaries. In Zone D, maximum non-harmful releases will be made to the St. Lucie and Caloosahatchee estuaries when the lake stage is rising. Based upon field discussions with operators of the water control structures on the Lake Okeechobee Waterway, when moderate releases are required, they will be made first to the Caloosahatchee River and then to the St. Lucie Canal, if necessary. The reason is that the St. Lucie is a much smaller estuary with greater sensitivity to the freshwater releases. When larger releases are required, water must be discharged down both waterways.

Although the regulatory discharges can have negative effects on the St. Lucie and Caloosahatchee estuaries due to excessive freshwater flows into these ecosystems, the releases are necessary during high lake stages to avoid loss of life and property associated with hurricane-generated rainfall and waves. Run25 was designed to minimize large releases from the lake into the two coastal estuaries. It provides for pulse releases (Levels I, II, and III) to these estuaries during periods of rising lake stage. The pulse releases, which mimic natural hydrology following rainfall events, were designed to avoid the adverse ecological effects of moderate releases. The receiving estuaries are able to absorb the pulses without prolonged salinity or ecological effects. The number "3" in the name (OS25-3) represents three levels of pulse releases that simulate inflow hydrographs to the estuaries following rainfall events. These discretionary releases occur within Zone D and are designated as Levels I-III in Figure 1-3. The pulse releases were designed to provide more natural regulatory discharges from the lake, reducing salinity effects of regulatory releases on the estuaries without compromising any of the other lake management objectives. While the pulses are effective for moderate regulatory releases, the prospect or occurrence of prolonged high lake stages can necessitate continuous releases from the lake into the estuaries.

As indicated in Table 1-1, Lake Okeechobee releases – measured in cubic feet per second (cfs) – may be directed toward (1) the Everglades via the agricultural canals to the Water Conservation Areas (WCAs), (2) the Caloosahatchee River via Spillway 77 (S-77), or (3) the St. Lucie Canal via Spillway 80 (S-80).

**TABLE 1-1**
**RUN25 RELEASE LEVELS (CFS) AND OUTLETS**

| Zone | Canal Releases | Caloosahatchee River | St. Lucie Canal |
|---|---|---|---|
| A | Pump maximum practicable to WCAs | Up to maximum capacity at S-77 | Up to maximum capacity at S-80 |
| B | Pump maximum practicable to WCAs | 6,500 cfs at S-77 | 3,500 cfs at S-80 |
| C | Pump maximum practicable to WCAs | Up to 4,500 cfs at S-77 | Up to 2,500 cfs at S-80 |
| D | Pump maximum practicable to WCAs | Maximum non-harmful discharges to estuary when stage rising | Maximum non-harmful discharges to estuary when stage rising |
| E | No regulatory discharge | No regulatory discharge | No regulatory discharge |

Source: SFWMD. Simulation of Alternative Operational Schedules for Lake Okeechobee. 1998.

## 1.4 ALTERNATIVE REGULATION SCHEDULES

Four alternative regulation schedules are currently being evaluated in order to identify the optimal plan to balance the competing management objectives for Lake Okeechobee. Each alternative regulation schedule stipulates the timing, magnitude, duration, and outlets for the regulatory water releases. The regulatory schedules were primarily designed to manage the lake when water levels are high. However, the regulation of high lake levels directly affects the frequency and duration of intermediate and low lake levels, since they determine how much water is stored in the lake during the wet season for use during the dry season.

Achieving an optimal regulation schedule is problematic for two principal reasons. First, the large number of competing management objectives complicates the analysis. Second, the climate of south Florida presents significant water management challenges. Distinct wet and dry seasons (beginning in mid-May and mid-October, respectively) and the precipitation potential of tropical storms must be included in all management decisions regarding the lake.

The four alternative regulation schedules build upon the SFWMD research that developed Run25. The first alternative schedule is OS22AZE (known as Run22AZE). This schedule was developed by the Lake Okeechobee Technical Advisory Committee with particular consideration for protecting the lake's littoral zone ecosystems. This schedule: (1) includes Run25 features that minimize salinity impacts on the Caloosahatchee and St. Lucie estuaries, (2) adds a regulation zone during low stages in which releases would be made only southward to the Everglades, and (3) allows for a large increase in stage during the beginning of the wet season.

The second alternative was proposed by the Corps. Known as COEREC, this schedule is similar to Run25, but it also: (1) includes the lower zone introduced by Run22AZE and (2) allows for increased storage (relative to Run22AZE) immediately after the peak of the hurricane season.

The third alternative schedule was developed by the Hydrologic Systems Modeling (HSM) Division of the SFWMD. Known as HSMREC, this schedule was developed during water supply planning for the LEC. It includes the new lower regulation zone contained in Run22AZE and COEREC. However, HSMREC also offers guidelines for adjusting water releases for each zone based on six-month inflow forecasts developed using climatic data. This provides additional flexibility in lake releases within each zone.

The fourth alternative schedule, known as WSE for Water Supply and Environment, was also developed by the HSM Division of the SFWMD. This regulation schedule was the result of intensive efforts by the SFWMD to formulate a schedule that better balances the competing management objectives for Lake Okeechobee. As implied by its name, the WSE regulation schedule was specifically developed to improve the water supply function of Lake Okeechobee and to protect the lake's littoral zone from excessive lake stage fluctuations. This schedule incorporates the most desirable features of the existing regulation schedule and the other three alternative schedules. This schedule was developed based on the experience of the HSM staff, as well as on input received from LORSS public meetings held in the spring of 1998, from the U.S. Fish and Wildlife Service, and from the Florida Game and Freshwater Fish Commission.

## 1.5 METHODOLOGY

There were three considerations that dominated the development of methodologies to evaluate the economic effects of the alternative regulation schedules. First, the SFWMM provided a powerful tool to evaluate the hydrologic and economic effects of the alternative schedules. Second, to assess the effects of the alternative regulation schedules, the with- and without-project future conditions must be compared. Third, some economic effects of the alternative schedules must be estimated through economic interpretation of hydrologic and ecological effects of the alternative plans. These considerations and the resultant methodologies used in this investigation are discussed below. Additional information regarding the methodologies is provided in subsequent chapters devoted to specific categories of potential economic effects of the alternative regulation schedules.

### 1.5.1 South Florida Water Management Model

The SFWMM is the principal analytical tool being used in the LORSS to evaluate and compare the hydrologic effects of the alternative regulation schedules. The SFWMM is a regional-scale, continuous-simulation, hydrologic model that was developed by the SFWMD. It simulates the hydrology and water management of southern Florida from Lake Okeechobee to Florida Bay. As illustrated in Figure 1-4, the SFWMM spans a region that includes most of Florida south of Lake Okeechobee. Of this region, 7,600 square miles are contained in a 2-mile by 2-mile model grid which is used to simulate system-wide hydrologic responses to daily climatic parameters (rainfall and evapotranspiration). While some tributaries to Lake Okeechobee, such as the Kissimmee River, are included in the model, they are not simulated with the 4 square-mile grid cells. Similarly, the Caloosahatchee and the St. Lucie basins – both part of the LOSA – are not included in the grid. However, LOSA sub-areas to the east and south (i.e., the EAA and northern Palm Beach County) are included in the grid. Northern Palm Beach County (LOSA Sub-Area 1) is designated as LEC Service Area 4 in the SFWMM.

The SFWMM simulates infiltration, percolation, evapotranspiration, surface and groundwater flows, levee underseepage, canal-aquifer interaction, current or proposed water management structures, and current or proposed operation rules. The model does not allow for changes in land use/cover and associated infrastructure for the simulation period. As a result, the simulations represent the response of a fixed structural and operational scenario to historic climatic conditions. The current version of the model includes climatic data from 1965-1995, allowing (over 11,000 sequential) daily simulations over a 31-year period.

The SFWMM is an operational model whose primary purpose is to assist the SFWMD in optimizing water management and allocation decisions. The model was not designed to conduct economic analysis, but does include many indicators of hydrologic change which can have economic consequences. To assist in estimating the economic effects of water management decisions, the SFWMD developed the Economic Post-Processor (EPP) to estimate the economic effects of cutbacks in agricultural and urban water supply during drought periods. The EPP was used in the LORSS economic analysis to estimate the impacts of the alternative regulation schedules on agricultural and urban water supply.

### 1.5.2 Comparison of With- and Without-Project Conditions

The economic effects of the alternative regulation schedules were determined by comparing the with-project conditions to the current regulation schedule (i.e., the without-project condition). Using the SFWMM as the principal tool for evaluating the economic effects of alternative regulation schedules required some practical modifications to the traditional analytical procedures used in Corps water resource planning studies. In traditional feasibility studies, a probabilistic analysis is conducted to forecast conditions throughout the planning period (typically 50 years), both with and without implementation of a project. "Average annual" economic impacts are estimated by evaluating a range of possible future conditions, weighting the likelihood (i.e., probability) of these conditions by their economic effects, and then statistically combining them. The difference between "average annual" with- and without-project conditions constitutes the net annual economic impacts of the alternative plans.

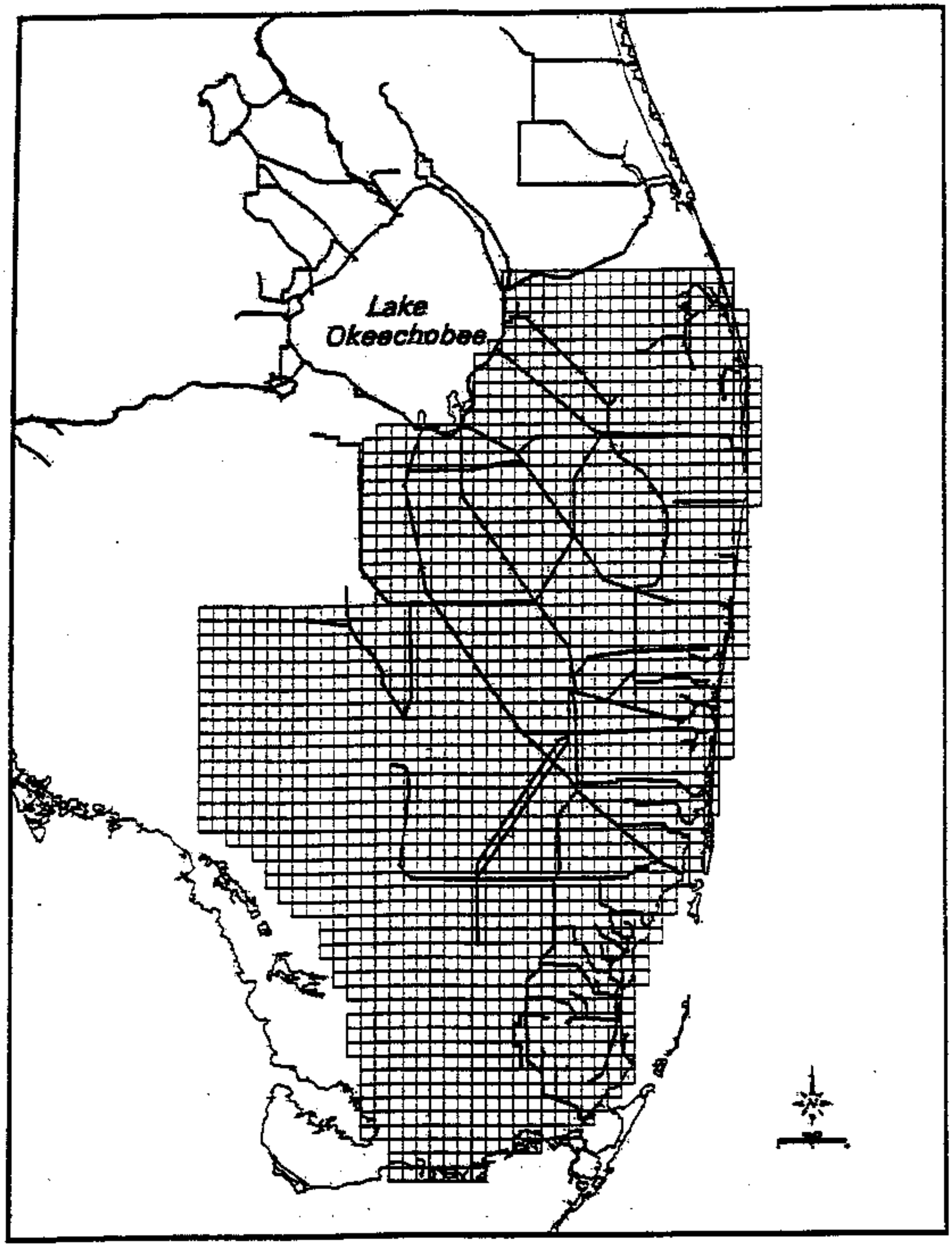



**FIGURE 1-4**
**SFWMM BOUNDARIES**

Source: South Florida Water Management District. Simulation of Alternative Operational Schedules for Lake Okeechobee. 1998.

This type of with- and without-project analysis had to be modified for the LORSS to account for the limitations imposed by the SFWMM. As stated previously, the SFWMM is a simulation model which equally weighs each of the days in the 31-year simulation period. It was not practical to use the SFWMM to determine the likelihood of occurrence of any given hydrologic event for two principal reasons. First, while the 31 years of past climate data are considered representative of future climate conditions, they are of insufficient duration to assign frequencies of occurrence to specific simulated hydrologic events (e.g., 25-, 50-, or 100-year return period events). Second, the regional scale of the SFWMM greatly complicates the assignment of frequencies to specific hydrologic conditions in the regional water management system.

Unfortunately, in this investigation it was not possible to effectively compare the present (1990) and future conditions (2010) for agricultural and urban water supply. It would be desirable to evaluate the effects of anticipated socioeconomic and land use changes in south Florida from 1990 to 2010 by comparing model outputs from these two scenarios under identical regulation schedules and other modeling parameters. The socioeconomic and land use changes in south Florida expected to occur in the absence of any plan implementation could provide important contexts for the expected effects of the alternatives. However, the SFWMM runs conducted for 1990 and 2010 have differences in modeling parameters that exceed socioeconomic and land use changes over time. This is not surprising, since structural and operational changes to the regional water management system would be expected over a 20-year period. While comparisons of the 1990 and 2010 scenarios cannot be used to isolate the effects of socioeconomic and land use changes over time, they do illustrate the stress on the regional water management system that is in part the result of these changes. The additional changes contained in the 2010 scenario include: (1) water quality best management practices in the EAA (which greatly increase evapotranspiration water losses to the atmosphere from the EAA), (2) increased water deliveries to the Seminole Indian reservations, and (3) the location of additional water supply wells at existing coastal wellfields in the LEC, a simplifying modeling assumption that is counter to SFWMD policy for reasons of coastal aquifer protection from salinity intrusion.

### 1.5.3 Hydrologic Changes and Economic Effects

Changing the regulation schedule for Lake Okeechobee has implications for water management throughout south Florida. The most direct effects of the alternative schedules will be on lake levels and on releases from the lake to the Everglades, to the Lower East Coast, and to tide via the Caloosahatchee River and the St. Lucie Canal. The potential economic impacts of the alternative regulation schedules are secondary consequences of hydrologic changes associated with the schedules. Figure 1-5 traces the causal linkages between the alternative regulation schedules and the different categories of economic effects.

Some categories of economic impact, such as urban and agricultural water supply effects, can be estimated directly from SFWMM-simulated hydrologic changes associated with each alternative regulation schedule plan. Other economic effects, such as commercial and recreational fishing impacts in the St. Lucie and Caloosahatchee estuaries, are less directly linked to the hydrologic changes resulting from the alternative regulation schedules. In this latter case, the chain of cause and effect includes: the impacts of project-induced changes in water release rates, the impacts of changes in release rates on the productivity of the fisheries, and the impacts of changes in the

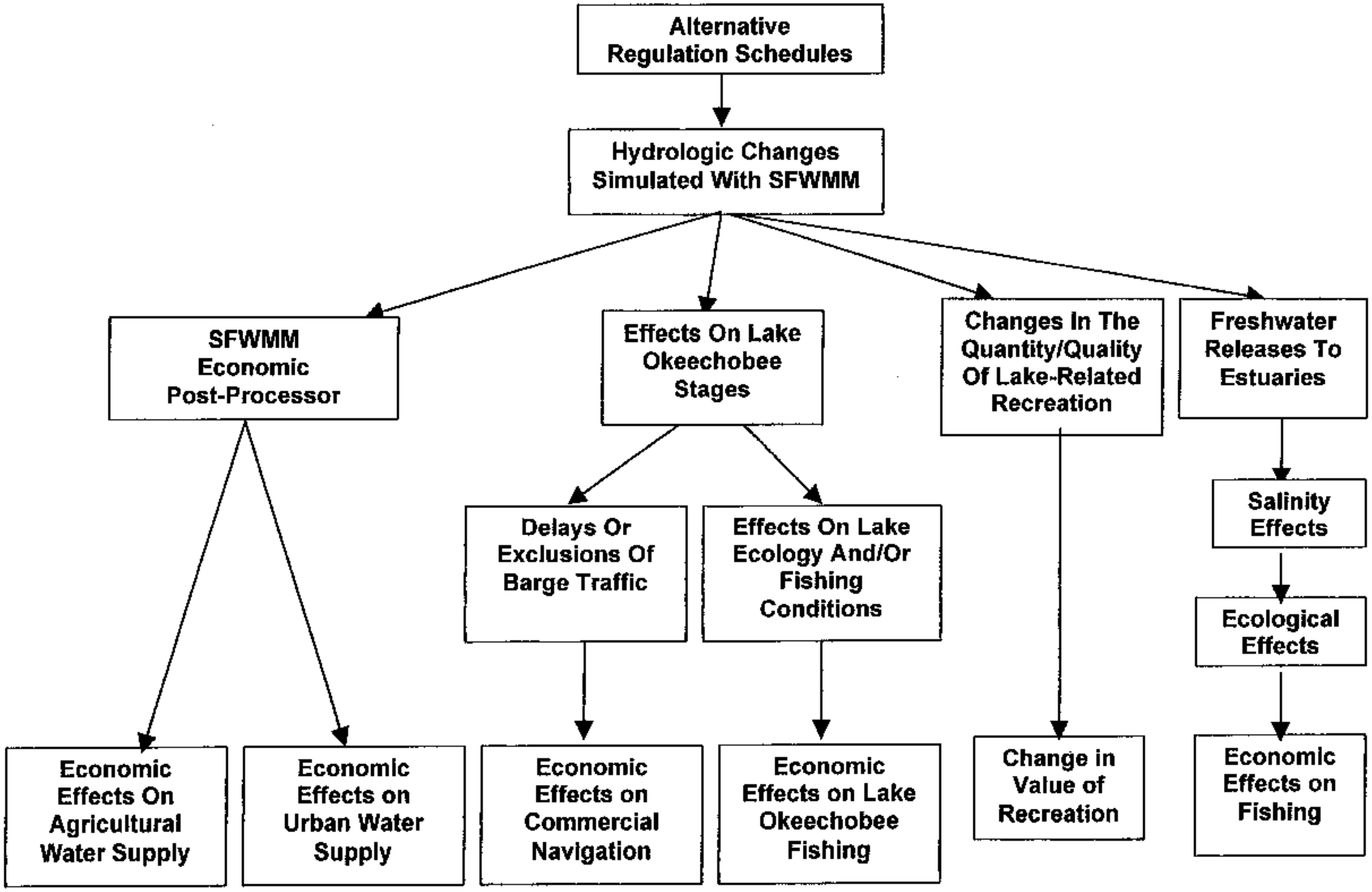



**FIGURE 1-5**
**SOURCES OF ECONOMIC EFFECTS**

fisheries on the net income of commercial fishing operations and the quality of recreational fishing experiences. As will become evident throughout this analysis, these chains of cause and effect have important consequences for quantification of the economic effects of the alternative plans. Economic analyses cannot be applied to estimate the value of physical or ecological impacts of the alternative plans if those impacts cannot first be defined and quantified.

## 1.6 PRIOR STUDIES

The Natural Resources Conservation Service (NRCS) conducted earlier studies that supported this investigation. The NRCS was previously engaged in an interagency agreement with the Corps to perform agricultural water supply impact analyses. NRCS personnel involved in the interagency cooperation provided valuable information and insight for this study.

In addition, the SFWMD performed a series of analyses that served as inputs to this investigation. These include the Simulation of Alternative Operational Schedules for Lake Okeechobee (1998) and a series of SFWMM runs which used the economic post-processor to simulate the economic effects of water supply shortages associated with the alternative regulation schedules.

## 1.7 ORGANIZATION OF THIS REPORT

The following chapters explore the potential economic effects of the alternative lake regulation schedules on: agricultural water supply (Chapter 2); M&I water supply (Chapter 3); navigation (Chapter 4); recreation (Chapter 5); commercial fishing in Lake Okeechobee (Chapter 6); and commercial and recreational fishing in the St. Lucie and Caloosahatchee estuaries (Chapter 7). Each of these chapters contains detailed discussions of the potential NED effects of the alternative regulation schedules. The secondary and indirect effects identified in the RED account are presented in Chapter 8.

# 2. AGRICULTURAL WATER SUPPLY

## OVERVIEW

Agriculture in south Florida generates approximately $3.8 billion in annual economic activity. Agricultural activity in south Florida is concentrated in the Everglades Agricultural Area (EAA), to the south and east of Lake Okeechobee; and in rural areas within the Lower East Coast (LEC), comprised of Dade, Broward, and Palm Beach counties. Principal crops include sugarcane, vegetables, tropical fruit, citrus, sod, ornamental plants, and nursery production. Agriculture in south Florida is supported by the region's abundant rainfall – approximately 59 inches along the Lower East Coast (LEC) and approximately 49 inches in the middle of the peninsula. Unfortunately, this rainfall is not distributed uniformly throughout the year, since the region has distinct wet (May through September) and dry (October through April) seasons. During the dry season, and especially when precipitation is below normal (i.e., droughts), supplemental irrigation is required for much of the region's agriculture.

During droughts, agricultural water users have higher irrigation water demands, since evapotranspiration is high and soil moisture is depleted. However, during these periods of high water demand, water supplies usually are at their lowest levels. Consequently, agricultural water users do not always receive as much water as they would like. Irrigation water shortages can have negative economic consequences for farmers, since water stress can reduce crop yields and can induce crop mortality. Residential water users in urban areas of the LEC can also experience shortages of irrigation water, which is needed for urban and suburban landscaping. These shortages can also have negative economic consequences for landscaping and can result in diminished aesthetics (i.e., brown lawns) and renovation or replacement costs for expired turf or ornamental landscaping.

The Lake Okeechobee Service Area (LOSA), which includes the EAA, is more dependent on agricultural water supplies from Lake Okeechobee than the LEC. During periods of normal rainfall, agricultural – and urban – water users in the LEC do not require supplemental water from the lake. In addition to rainfall, the LEC receives significant wellfield recharge via easterly seepage from the Water Conservation Areas under the north-south levee system which serves as a boundary between the LEC and the Everglades. However, during prolonged drought events, significant volumes of water from Lake Okeechobee can be required by the LEC to supplement local water supplies and to prevent saltwater intrusion into wellfields.

The potential effects of the alternative regulation schedules on agriculture are based on the magnitude and frequency of irrigation water shortages. The economic effects of the alternative regulation schedules are the differences between the expected crop losses resulting from agricultural water shortages under with- and without-project conditions.

### 2.1 AGRICULTURE IN THE LAKE OKEECHOBEE SERVICE AREA

As described in the following profile of south Florida agriculture, there is substantial agricultural activity in the LOSA and the LEC. Two levels of detail are presented in this study regarding land uses in the EAA – the largest area within the LOSA – and the LEC. Detailed information about acreages and crop mixes from several sources is presented for the EAA and the LEC. However, the estimates of agricultural land use for the with- and without-project conditions utilize less detailed and broader land use categories for the 1990 and 2010 scenarios contained in the SFWMM and EPP.

The use of broader land use categories in estimating economic effects reflects two practical considerations: (1) the need to forecast future agricultural land uses and (2) the spatial resolution of the SFWMM, which is the primary analytic tool for evaluating the alternative regulation schedules. Agricultural land uses can be extremely difficult to forecast, since crop types can change from year to year, and larger scale land use changes – such as the conversion of agricultural land to urban and suburban uses – can occur rapidly as well. As a result, it is more realistic to forecast future land uses with broad land use categories. Regarding the limitations of the SFWMM, the 4 square-mile resolution of the model's grid cells is coarse relative to the assessment of agricultural water supply impacts of the LORSS alternative schedules. The model was designed to simulate the hydrology of south Florida. Land use patterns in south Florida represent static inputs to SFWMM hydrologic simulations. The hydrologic implications of changes in land use can only be evaluated in this model by comparing the results of separate simulations. The SFWMM land use estimates for 1990 and 2010, which are utilized in this investigation, are critical components in the analysis of with- and without-project conditions. They affect most aspects of water management in south Florida, including the economic aspects. These estimates were utilized by the economic post-processor in the runs conducted for this study and are presented below.

Table 2-1 presents the acreages of irrigated agriculture in the sub-areas of the LOSA. As indicated in this table, there are 742,668 acres of irrigated land in the LOSA. Agricultural activities in the LOSA sub-areas are described below. See Figure 1-3 for the sizes and locations of the sub-areas.

**TABLE 2-1**
**LOSA IRRIGATED ACREAGE**

| LOSA Sub-Area | Irrigated Acreage |
|---|---|
| 1. EAA | 541,878[1] |
| 2. North Shore | 13,380[2] |
| 3. Caloosahatchee Basin | 138,337[3] |
| 4. St. Lucie Basin | 49,073[4] |
| **Total LOSA** | **742,668** |

Sources:
[1] : See Table 2-2 below.
[2] : Hall, C.A. Lake Okeechobee Supply-Side Master Plan. SFWMD. 1991.
[3] : SFWMD. Long-Range Demands for the Caloosahatchee Basin. 1997.
[4]: SFWMD. Long-Range Demands for the St. Lucie Basin. 1997.

### 2.1.1 Everglades Agricultural Area (EAA)

The EAA encompasses an area of approximately 593,000 acres. As indicated in Table 2-2, the EAA contains approximately 542,000 acres under cultivation. Sugarcane is the dominant crop type, accounting for 90% of the land under cultivation. The remaining 10% under cultivation is occupied by rice, row crops, and sod. The row crops include corn, celery, radishes, and lettuce.

**TABLE 2-2**
**AGRICULTURAL LAND USES IN THE EAA**

| Crop | Acreage | Percent of Total |
|---|---|---|
| Sugarcane | 485,881 | 90% |
| Rice[1] | 25,000 | 5% |
| Row Crops | 16,689 | 3% |
| Sod | 13,258 | 2% |
| **Total EAA** | **541,878** | **100%** |

Sources: Hendry and Palm Beach County Tax Appraisers, 1997
[1] IFAS Extension Agent, Palm Beach County.

The EAA is very well suited to sugar production. There are thick organic muck soils and adequate water supplies from precipitation and from Lake Okeechobee via the EAA network of water supply canals. Multiple crops can be harvested from a single planting. Planting typically occurs in the autumn months. The plant cane will be ready for harvest after approximately 16 months. The root stock is left in place, and the first regrowth (i.e., ratoon) can be harvested again in another 11 months. Again, the root stock is left in place, and a second ratoon will be ready in another 11 months. Some farms will harvest up to four ratoons, but yields decline with each successive ratoon. As a result, many farmers replant after the second ratoon in order to keep cane yields high.

The harvest season is from October to March. After harvesting the last ratoon, farmers must decide whether to replant immediately or leave the field fallow until the following autumn. If there is successive planting, more cane can be harvested the following year. However, if the field is left fallow, yields would be higher once the field is replanted. Many farmers will balance these competing incentives by replanting half of the field and leaving the other half fallow. For this reason, Alvarez (1997) estimates that following crop distribution would be typical of many sugarcane farms: plant cane (25%), first ratoon (25%), second ratoon (25%), fallow (12.5%), and roads, canal, ditches (12.5%). Sugarcane grown in the EAA is converted into raw sugar at the seven sugar mills found in the area. Sugarcane must be milled rapidly after it has been harvested to avoid degradation of its sugar content. The raw sugar is then shipped to sugar refineries located throughout the United States where it undergoes additional processing.

The EAA is not uniformly well suited to sugar production. In general, land that is closer to Lake Okeechobee (i.e., more northern) is better suited for sugarcane than areas to the south. The areas close to the lake are protected from frosts by the climatic influence of the lake. In addition, the muck soils are deeper in the northern part of the EAA. Consequently, soil subsidence is not as much of a problem as in areas with relatively shallow soils in the southern EAA. Subsidence occurs when the land is drained and the organic soils begin to oxidize. The surface elevation of the land subsides toward the underlying limestone bedrock. In some southern zones of the EAA, subsidence has reduced the soil layer to less than 6 inches, the point at which farming is typically no longer profitable. Another negative aspect of subsidence is that as the soil layer thins, the soil chemistry changes, and the application of additional nutrients (i.e., fertilizer) is required.

Most of the non-sugar crops in the EAA are grown by farmers who also grow sugarcane. Many farmers rotate their vegetable cultivation between celery and sweet corn; others rotate lettuce and sweet corn. Sod is grown primarily in the southern portion of the EAA, an area of declining suitability for sugarcane due to subsidence. Rice cultivation is small, but it could grow in importance. Rice cultivation is being encouraged by the University of Florida's Institute for Food and Agricultural Science (IFAS) to retard soil subsidence. Rice production is also recommended by the SFWMD as way to reduce phosphorus loading into the Everglades, since rice requires less fertilizer than sugarcane. However, under prevailing market conditions rice profitability is low relative to sugarcane.

The spatial resolution of the SFWMM is too coarse to fully reflect the above land use profile of agriculture in the EAA. For example, the SFWMM assigns all of the EAA acreage to sugarcane (i.e., all of the grid cells are designated as sugarcane), since the non-sugar crops in the EAA are spatially diffuse and do not dominate a single grid cell. Therefore, only sugarcane is registered under the model's 4 square-mile grid cell resolution. As a result, the information in Table 2-2 is consistent with the SFWMM land use estimates of total acreage, but not acres devoted to sugarcane cultivation. As will be evident later in this report, the model's homogenization of agriculture in the EAA has implications for the calculation of economic impacts of the alternative regulation schedules.

The land use projections used in the SFWMM estimate that sugar cultivation (and perhaps agriculture in general) in the EAA will decrease in the future, from 529,920 acres in 1990 to 491,520 acres by 2010. The projected decrease is due primarily to the SFWMD's purchase of agricultural land for Stormwater Treatment Areas, and perhaps to anticipated soil subsidence as well.

### 2.1.2 Caloosahatchee and St. Lucie Basins and the North Shore

Agricultural land uses for the Caloosahatchee and St. Lucie basins are presented in Tables 2-3 and 2-4. The agricultural water needs in these basins that are not met with local sources are met with water released from Lake Okeechobee into these two outlet waterways. The Caloosahatchee basin is an area of expanding agricultural activity with increasing agricultural water demands. No land use data was available for the North Shore sub-area.

**TABLE 2-3**
**AGRICULTURAL LAND USES IN THE CALOOSAHATCHEE BASIN**
**1994**

| Crop | Acreage | Percent of Total |
|---|---|---|
| Citrus | 78,113 acres | 56 % |
| Sugarcane | 50,359 acres | 36 % |
| Vegetables | 8,091 acres | 6 % |
| Sod | 1,296 acres | 1 % |
| Ornamentals | 478 acres | <1 % |
| **Total** | **138,517 acres** | **100 %** |

Source: SFWMD. Draft Long-Range Demands for the Caloosahatchee Basin. 1997.

# TABLE 2-5
## LEC AGRICULTURAL LAND USE DISTRIBUTION: 1990, 2010
## (ACRES)

| Land Use | SA1 | | SA2 | | SA3 | | Northern Palm Beach County | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1990** | **2010** | **1990** | **2010** | **1990** | **2010** | **1990** | **2010** | **1990** | **2010** |
| **Urban** | 34,381 | 58,824 | 49,866 | 74,121 | 61,911 | 90,081 | 8,343 | 15,614 | 154,501 | 238,640 |
| **Nursery** | 4,140 | 6,474 | 608 | 2,478 | 2,622 | 10,133 | 143 | 541 | 7,513 | 19,626 |
| **Golf** | 10,644 | 13,588 | 7,891 | 8,982 | 3,232 | 4,165 | 2,993 | 6,573 | 24,760 | 33,308 |
| **Agricultural - LV** | 11,238 | 3,141 | 2,880 | 7 | 16,883 | 8,646 | 4,950 | 1,018 | 35,951 | 12,812 |
| a. Citrus | 11,207 | 3,141 | 2,880 | 7 | 6,190 | 0 | 4,949 | 1,018 | 25,226 | 4,166 |
| b. Avocado | 31 | 0 | 0 | 0 | 10,693 | 8,645 | 0 | 0 | 10,724 | 8,645 |
| **Agricultural - OV (tomatoes)** | 26,610 | 8,595 | 755 | 18 | 46,165 | 28,515 | 2,390 | 615 | 75,920 | 37,743 |
| **Agricultural - Other** | 7,026 | 1,806 | 2,744 | 2,756 | 1,097 | 3,198 | 49 | 0 | 10,916 | 7,760 |
| a. Sod | 2,434 | 748 | 1,469 | 2,723 | 347 | 3,198 | 49 | 0 | 4,299 | 6,669 |
| b. Sugar | 4,592 | 1,057 | 1,274 | 32 | 749 | 0 | 0 | 0 | 6,615 | 1,089 |
| c. Rice | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Total Agriculture** | **94,039** | **92,428** | **64,744** | **88,362** | **131,910** | **144,738** | **18,868** | **24,361** | **309,561** | **349,889** |
| **Total Service Area** | **430,808** | **430,808** | **401,920** | **401,920** | **744,960** | **744,960** | **227,840** | **227,840** | **1,804,800** | **1,804,800** |
| **% Represented** | **22%** | **21%** | **16%** | **22%** | **18%** | **19%** | **8%** | **11%** | **17%** | **19%** |

Source: SFWMD, 1997.

**TABLE 2-4**
**AGRICULTURAL LAND USES IN THE ST. LUCIE BASIN**
**1996**

| Crop | Acreage | Percent of Total |
|---|---|---|
| Citrus | 43,071 acres | 88 % |
| Vegetables | 5,538 acres | 11 % |
| Sugar Cane | 449 acres | 1 % |
| Nursery | 15 acres | <0.1 % |
| **Total** | **49,073 acres** | **100 %** |

Source: SFWMD. Draft Long-Range Demands for the St. Lucie Basin. 1997.

## 2.2 AGRICULTURE IN THE LOWER EAST COAST

The three service areas of the LEC also contain large areas of agriculture. Table 2-5 presents the 1990 and 2010 agricultural land use patterns contained in the SFWMM for the LEC service areas, including northern Palm Beach County (SA-4). These values were extracted from the SFWMM by the economic post-processor. The post-processor considers only those SFWMM land use categories for which economic effects of water shortages can be generated. As indicated in Table 2-5, the post-processor uses six broad categories of land use: urban, nursery, golf courses, low-volume (LV) irrigated agriculture (such as citrus and avocado), overhead (OV) irrigated agriculture (such as tomatoes), and other agriculture (including sod, sugarcane, and rice). As suggested in this table, tomatoes are intended to represent truck vegetables grown with overhead irrigation systems. The categories of urban (turf) and golf – which is primarily suburban – land uses are included because they are maintained with irrigation water that is supplemented directly or indirectly with water from the regional water supply system. While these two land uses are not agricultural, they will be included in the discussions of agricultural water supply throughout this report.

Figures 2-1 and 2-2 illustrate the percentage changes of agricultural land uses under the 1990 and 2010 scenarios for each of the three service areas of the LEC and the entire LEC, respectively. Northern Palm Beach County is included in Table 2-5. As indicated in Figures 2-1 and 2-2 (and Table 2-5), the three LEC service areas and northern Palm Beach County are anticipated to have large increases in urban land uses between 1990 and 2010. These increases suggest conversion of agricultural land. However, as indicated in the table, these land use categories represent less than one-quarter of the land use in the service areas. The land use profile presented in this table is therefore not comprehensive, since the economic post-processor only draws upon those categories for which economic impacts can be derived. This explains why the land use sub-totals for the 1990 and 2010 scenarios in Table 2-5 are not in agreement.

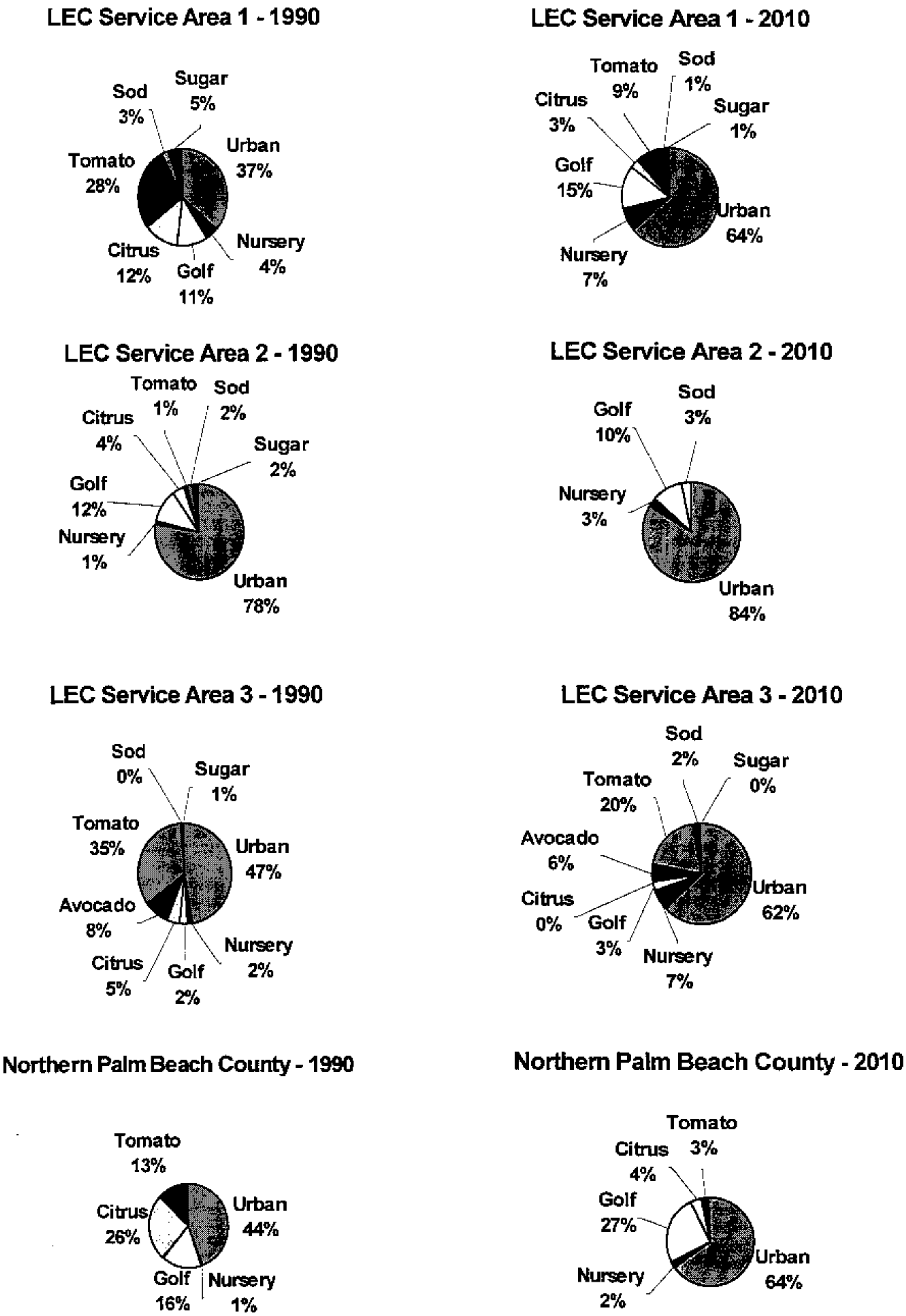
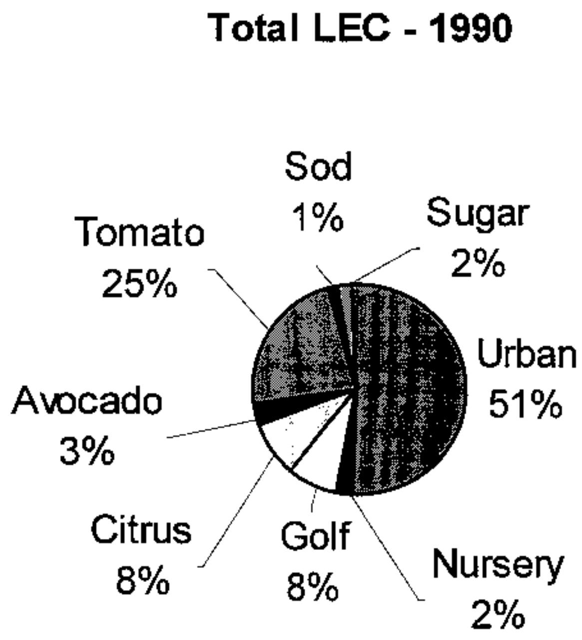



**FIGURE 2-1**
**LEC SERVICE AREAS' AGRICULTURAL LAND USE: 1990, 2010**



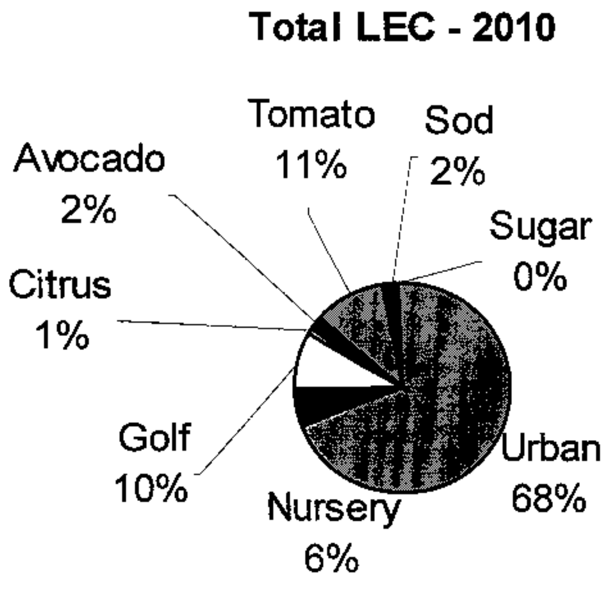




**FIGURE 2-2**
**LEC AGRICULTURAL LAND USE: 1990, 2010**

## 2.3 AGRICULTURAL WATER MANAGEMENT DURING SHORTAGES

To estimate the potential damages associated with shortages in agricultural water supply, it is necessary to understand how irrigation water supplies are managed during drought periods. Agricultural water use during droughts is the result of regional decisions made by water management institutions, such as the SFWMD, and local decisions made by water users, including individual farmers. These two levels of water management decision making during droughts are discussed below.

### 2.3.1 Regional Water Management

The SFWMD monitors hydrologic conditions throughout south Florida. Current hydrologic and water use data is compared to historic data to determine: (1) whether present and anticipated water supplies are sufficient to meet the present and anticipated needs of water users and (2), whether serious harm to the region's water resources can be expected, including saltwater intrusion into freshwater aquifers or adverse fish and wildlife effects.

Factors considered in estimating present and anticipated water supplies include:

- Historic, current, and anticipated levels in surface and ground waters,
- Historic, current, and anticipated flows in surface waters,
- The extent to which water may be transferred from one source to another,
- The extent to which water use restrictions might enhance supplies,
- Historic, current, and anticipated demands of natural systems, and
- Historic, current, and anticipated seasonal fluctuations in rainfall.

Factors considered in estimating present and anticipated water demands include:

- Estimated current, and anticipated demands of permitted and exempt users,
- Demands of users whose water supply is established by federal law,
- Anticipated seasonal fluctuations in user demands, and
- The extent to which user demands may be met from other sources.

When the current or future water supplies are not expected to meet water demands, the SFWMD may institute a series of progressively more severe conservation (demand management) measures to conserve water supplies. The SFWMD developed the Water Shortage Plan in 1982 following a severe drought during which Lake Okeechobee reached its all-time record low level of 9.75 feet NGVD. The plan provides specific guidelines for water restrictions, which are based on the type of use and the severity of the drought. Included within the plan are four progressively more severe water shortage phases (I-IV) which initially request and later require cutbacks in water use throughout south Florida. Included within the Water Shortage Plan are water use reductions which are expected to range up to 15% of estimated demand under Phase I and up to 60% of estimated demand under Phase IV.

Shortage declarations by the SFWMD can be triggered by salinity intrusion into coastal aquifers threatening utility wellfields or by low lake levels in Lake Okeechobee relative to seasonal norms. The declarations are typically continued until it is clear that the imbalance between water supplies and water demands is resolved, avoiding to the extent possible an on/off whipsaw of shortage declarations.

If droughts are localized, the SFWMD will attempt to manage the regional water supply system to move water from areas of surplus to areas of deficit. The shortage phase declarations can be scaled to the municipal, utility, county, service area, or regional level commensurate with the extent of the water shortage. For regional droughts, such as those triggered by low Lake Okeechobee levels, the water shortage phases are instituted to reduce water demand on a system-wide basis. To date, the specific use restrictions of the Water Shortage Plan have been invoked three times: 1982, 1985, and 1989 (Hall, 1991).

The four phases of water supply shortages in the Water Shortage Plan stipulate cutbacks by water users in the LEC, including agricultural water usage. However, the phased restrictions in the Water Shortage Plan have not been applied to agriculture in the LOSA. Agricultural water users in the LOSA are subject to supply-side management (SSM) for Lake Okeechobee. The required agricultural water use restrictions of the Water Shortage Plan are assumed to have been met when LOSA water users comply with the lake's SSM plan.

During severe droughts, water levels in Lake Okeechobee drop as inflows are exceeded by water losses from releases and evaporation. If water levels fall sufficiently, SSM is instituted for the lake. The amount of water available for use is a function of anticipated rainfall, evaporation, and water needs (for the balance of the dry season) in relation to the amount of water currently in storage. The SSM schedule for the lake is illustrated in Figure 2-3. SSM begins when lake levels fall below the watch and warning levels and enter Zone A. The upper limit of Zone A represents a storage amount sufficient to meet all demands in the following year provided that all basins receive at least 100% of normal rainfall during the year. Each of the zones represents storage levels with assigned probabilities of shortage. For example, if the stage in the wet season is in Zone A or lower, the area has a 50% probability of a water shortage in the following winter and spring (i.e., dry season).

The SFWMM is used to calculate weekly water allocations for each agricultural water user in the LOSA. Available water supplies are estimated based on lake levels and evaporation and rainfall estimates. Allocations are then made by comparing normal water requirements with available water supplies.

The SSM rules for the EAA are bounded by SFWMD policy which commits to supplying a minimum of one-third of the supplemental irrigation needs for agriculture in this area. This lower limit of agricultural water supply is reflected in the SFWMM. This policy may effectively preclude crop mortality in the EAA during dry periods and limit drought effects on agriculture to reduced crop yields.

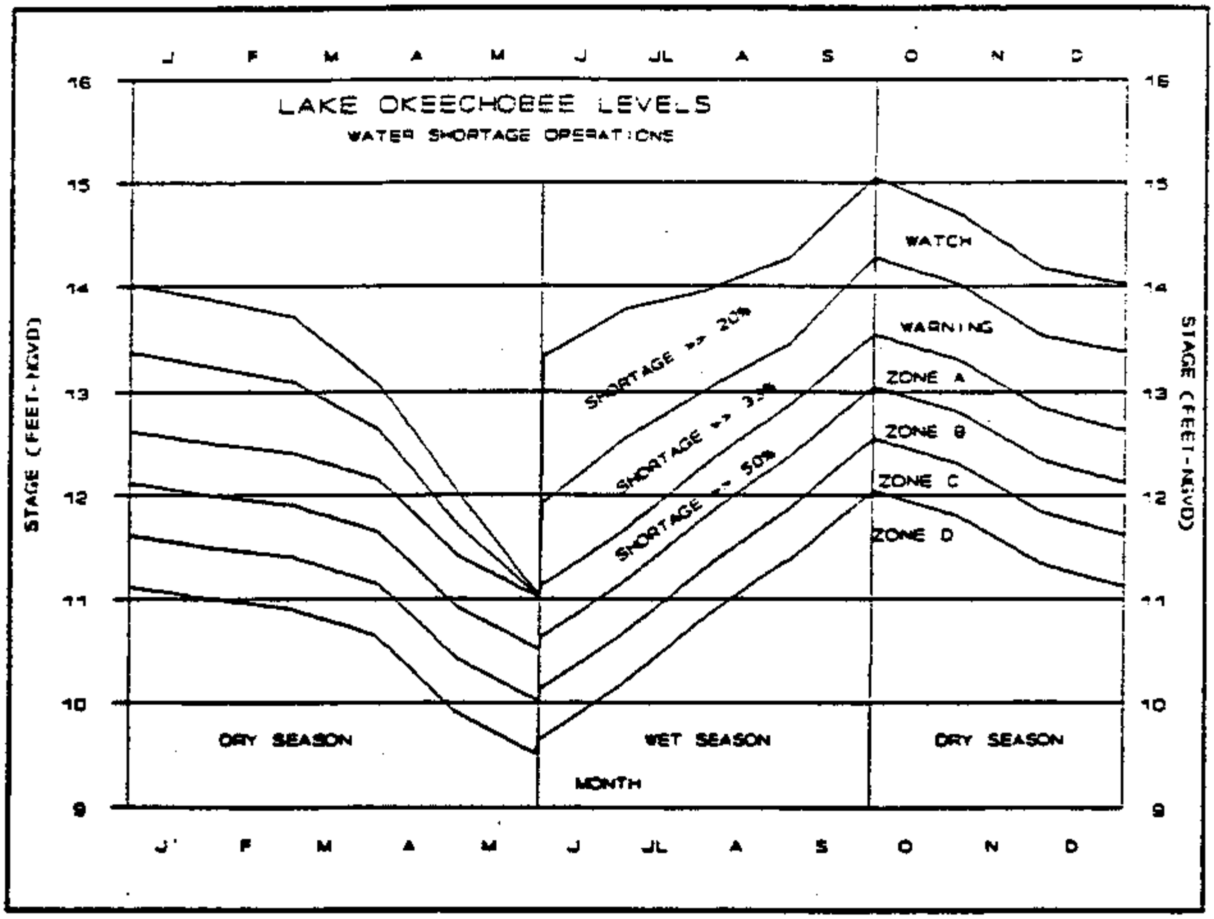



**FIGURE 2-3**
**LAKE OKEECHOBEE SUPPLY SIDE MANAGEMENT SCHEDULE**

Source: Hall. C.A. Guide for the Management of High Stages in Lake Okeechobee. SFWMD. 1992.

### 2.3.2 Local Water Management

For each crop and irrigation method in the LEC, the water use of farmers is specified by the Water Shortage Plan. Farmers in the LOSA have more flexibility in making water management decisions. Under SSM, water allocations to agricultural users in the LOSA are progressively cutback as shortages become more severe (Zones A to D). However, the SFWMD Governing Board may allow agricultural users to borrow against their seasonal allocation in the first four months of the dry season. The behavior of LOSA farmers in the face of water supply shortages is based on the vulnerability of their particular crops to water stress and the value of those crops. If plants do not receive sufficient moisture from precipitation or irrigation, particularly during critical stages in the growing season, evapotranspiration (ET) is reduced, and growth rates and yields can be significantly affected. Some crops are more vulnerable to water stress than others. For example, sugarcane is more tolerant to water stress than most vegetables. As a result of water stress, the sugar content of the cane will be reduced, but the entire crop will not be lost. In fact, some sugar farmers prefer dry conditions immediately prior to harvest, since it increases the sugar content of the cane. Vegetables, on the other hand, can quickly suffer large yield effects and crop mortality in response to stress from water shortages.

Changes in crop yield are a critical determinant of farm income and can induce changes in crop mix or farming practices. For farmers in the EAA who grow sugar and vegetables, their decision making during water shortages is based on expected crop-specific responses to water stress and the relative value of each crop. Farmers will allocate water on their lands based upon the greatest marginal value of the scarce irrigation water. When water allocations from the regional water system are reduced, farmers will typically give vegetables priority over sugar cane (Scheneman, 1997), because of the sensitivity and value of vegetable crops. As a result, vegetables and other non-sugar crops in the EAA are not expected to experience as great a cutback during shortages, since sugarcane will be the primary recipient of irrigation cutbacks.

Interviews conducted with a variety of experts on EAA agriculture indicate that farmers will generally borrow as much water as they can against their future allocation in order to fully satisfy the water needs of their crops for as long as possible (Personal Communications: Alvarez, 1997; Scheneman, 1997). Essentially, farmers in the EAA will accept the risk of extreme cutbacks later in the season in order to meet their full irrigation needs early in the season. Farmers weigh their present needs against their future needs with careful consideration. The type of crop, timing during the growing season, and anticipated cutbacks are included in their decision making. This risk-accepting behavior is supported by experience. During the 1981-1982 drought, widespread borrowing against seasonal water allocations by farmers in the EAA was reinforced by above-normal rainfalls later in the growing season, mitigating the deferred impacts of the drought (Hall, 1991). The SFWMD's policy of meeting at least one-third of the supplemental irrigation requirements of farmers in the EAA may give additional impetus for farmers to borrow against their seasonal water allocations.

Reductions in delivery of water from Lake Okeechobee to south Florida agriculture may or may not result in economic losses to farmers. The 1981-1982 experience cited above is testament to this uncertainty. There are a variety of factors which determine the actual economic impacts of shortages, including antecedent conditions, local precipitation during and after the cutbacks, crop types, and the timing of the cutbacks with respect to the growing season. Interviews with LOSA agricultural experts also suggest that farmers will not significantly modify their production activities during shortages. When shortages do occur, the water stress associated with irrigation cutbacks will result in yield reductions for the entire crop, since water stress will be uniform across the entire irrigated area. Therefore, the unit costs of crop production will not change significantly for different yield levels. Regardless of whether the crop is 100%, 80%, or 50% of potential yield, the unit costs of crop production will be the same. As will be evident later in this report, this has important implications for estimating the NED impacts of agricultural water supply shortages resulting from the alternative regulation schedules.

## 2.4 ECONOMIC POST PROCESSOR DEVELOPMENT AND FUNCTION

As stated previously, the SFWMD has developed an economic post-processor (EPP) to assess the monetary effects of agricultural and M&I water supply shortages. The EPP, which is embedded in the SFWMM, was designed to estimate the agricultural and M&I water supply impacts of physical or operational changes in water management in south Florida, such as modifying the regulation schedule for Lake Okeechobee. The utility of the EPP for estimating the potential economic effects of the alternative regulation schedules is examined below.

The EPP was originally developed to estimate the benefits of structural and/or operational improvements to the regional water supply system by monetizing the value of south Florida's unmet demands for agricultural and M&I water supply. As illustrated in Figure 2-4 and described below, the agricultural element of the EPP was developed through a five-part process.

### 2.4.1 Development of the AFSIRS Model

The Agricultural Field Scale Irrigation Requirement Simulation (AFSIRS) was developed at the Agricultural Engineering Department of the University of Florida (Smajstrla, 1990). This model predicts water requirements for maximum crop yields. It does not predict crop yields, but instead calculates the quantity and frequency of irrigation necessary to avoid water stress to crops. The program contains the data necessary to model all of the commercially important crops in Florida under various irrigation schemes and with a wide variety of soil types.

AFSIRS calculates irrigation requirements and evapotranspiration rates as a function of crop type, soil type, irrigation system, growing season, and climatic conditions. The model assumes that irrigation requirements are met from the unsaturated zone through rainfall or supplemental irrigation. As illustrated in Figure 2-4, the model draws upon four data files. The user specifies three sets of input parameters for the agricultural plot: soils, crops, and irrigation systems. These inputs are combined with time-series precipitation data and simulated potential and crop-specific evapotranspiration rates (PET and ET respectively). The model then calculates how much water is required by the selected crop at a particular point in its growing season under specific soil and climatic circumstances. AFSIRS has been successfully tested and applied in south Florida. The SFWMM contains an AFSIRS module that is used to estimate daily water requirements of irrigated agriculture in the LOSA and the LEC.

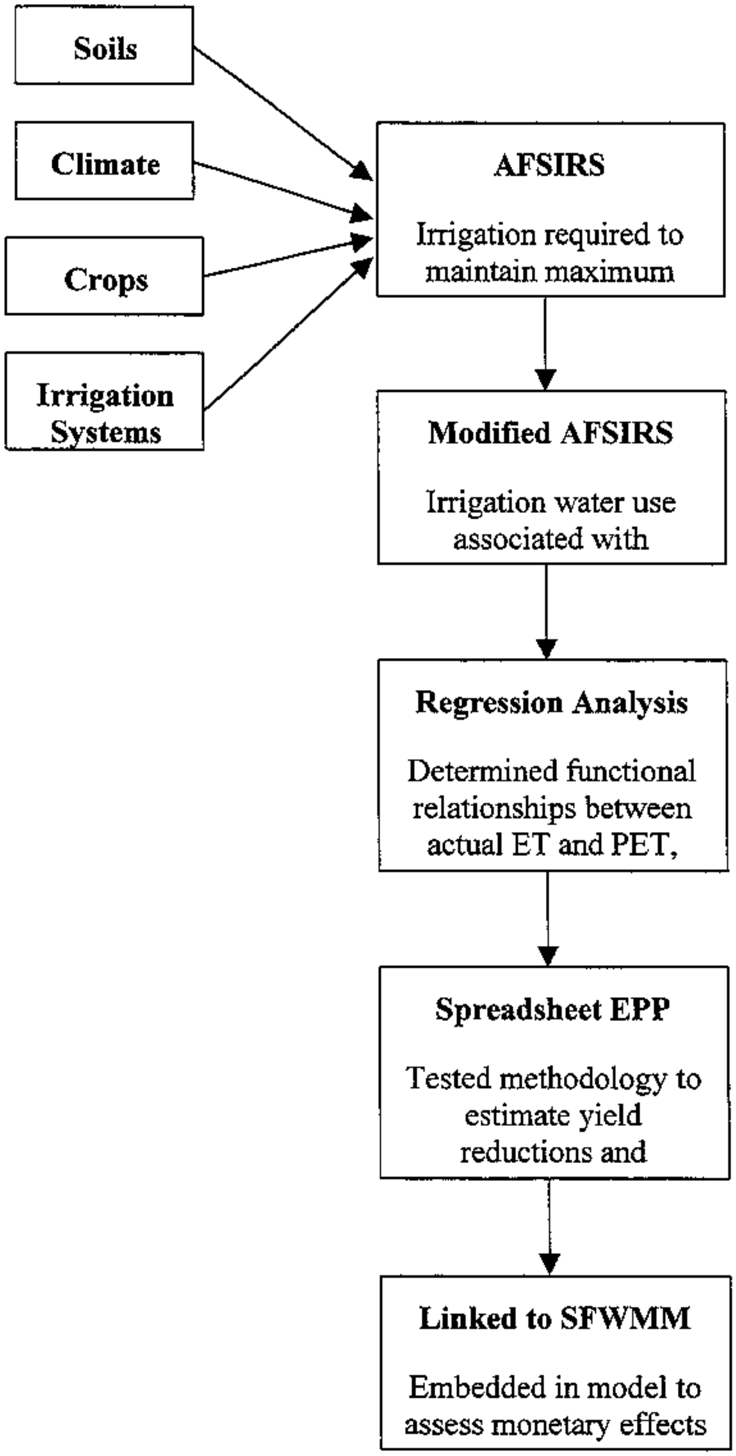



**FIGURE 2-4**
**DEVELOPMENT OF THE AGRICULTURAL ELEMEMT**
**SFWMM ECONOMIC POST-PROCESSOR**

### 2.4.2 Modification of the AFSIRS Model for Drought Applications

Thompson and Lynne (1991) of the IFAS modified the AFSIRS program for drought impact analysis. Among the modifications made by Thompson and Lynne was the introduction of the Stewart equation into the model. The Stewart equation relates the difference between actual ET and potential ET (PET) to changes in crop yield. The logical basis for the Stewart equation is that plants reduce their transpiration when they are water stressed, and this reduction is an indicator of stress-induced effects on crop yield. The Stewart equation is as follows:

$$1-(Y_{act}/Y_{max}) = \beta(1-ET_{act}/ET_{max})$$

where:

| | |
|---|---|
| $Y_{act}$ | = actual crop yield per acre (simulated) |
| $Y_{max}$ | = maximum crop yield per acre |
| $\beta$ | = crop specific output per irrigation level (Beta coefficient) |
| $ET_{act}$ | = actual evapotranspiration per acre (simulated) |
| $ET_{max}$ | = potential evapotranspiration (PET) |

According to Thompson and Lynne, the Stewart equation is widely accepted. The crop-specific Beta coefficients ($\beta$), which relate water stress to crop yields, are based on research conducted for the Food and Agricultural Organization of the United Nations (Doorenbos and Kassam, 1979). The Beta coefficients depend on the crop type and growth stage being modeled. Thompson and Lynne caution users of this model that the Beta coefficients contained in the program have been obtained from experimental data. For annual crops, single coefficients are included in the model for four growth stages: early vegetative, flowering, yield formation, and ripening. For perennials, it is more difficult to produce coefficients for specific growth periods. For example, it is well known that citrus is sensitive to water shortages during flowering. However, the actual flowering period will vary with climate and with soil moisture. This is problematic for AFSIRS, since it calculates irrigation requirements using the calendar date as a key to crop growth stage.

In the modified AFSIRS program, the user must specify actual yields ($Y_{act}$) as a proportion of the unconstrained yield ($Y_{max}$). The model uses the Stewart equation to simulate actual ET ($ET_{act}$). In the model, $ET_{act}$ is drawn from the unsaturated zone, and the water comes from rainfall or supplemental irrigation. Precipitation estimates contained in the climatic data file are used by the modified AFSIRS program to compute the supplemental irrigation required for the specified crop yields.

Thompson and Lynne (1991) attempted to validate the modified AFSIRS program. This was problematic however, since there were no subsequent agricultural droughts with which to compare the model's predictions. Instead, the model was tested against three crop-growth models which have been tested extensively in north Florida. The modified AFSIRS model generated results which were similar to the other models. Improvements were subsequently made to the model during the calibration process.

### 2.4.3 Regression Analysis

The SFWMD used the modified AFSIRS to determine the functional relationships between actual ET and PET, irrigation levels, and precipitation for a wide variety of crop and irrigation schemes (March, 1996). This was done by performing a series of model runs, specifying a range of different actual yields ($Y_{act}$): 100%, 75%, 60%, 50%, 40%, and 25%. This generated a series of simulated $ET_{act}$ values. Regression equations were then computed to relate modeled monthly ET to monthly PET, rainfall, and net irrigation. The general functional form of the regression equations is double (natural) logarithmic:

$$\ln (ET_{ijkl}) = \alpha + \beta_1 * \ln (PET_i) + \beta_2 * \ln (Raadj_i) + \beta_3 * \ln (Iradj_{ijkl})$$

where:

$ET_{ijkl}$ = actual ET in month i of crop j on soil type k for yield level l
$PET_i$ = Modified Penman-Monteith potential ET in month i
$Raadj_I$ = measured rainfall in month i
$Iradj_{ijkl}$ = simulated net irrigation in month i of crop j on soil type k at yield level l

(Note: $\beta_i$ here are regression coefficients, not the crop output factors in the Stewart equation)

### 2.4.4 Spreadsheet Prototype

The SFWMD developed a spreadsheet prototype of the EPP. During periods when available irrigation water supplies are less than what the AFSIRS model predicts is necessary to support maximum crop yields, the EPP estimates the potential reduction in agricultural revenues using the functions described above. The lower crop yields estimated using the regression functions are compared against maximum yields to determine changes in yield per acre. These values are then multiplied by the number of acres to estimate changes in total crop outputs. Crop outputs are multiplied by market prices to compute the potential revenue effects of water shortages.

### 2.4.5 Linkage to SFWMM

Once the spreadsheet prototype was successfully tested, the SFWMD embedded the EPP within the SFWMM. The SFWMM outputs of PET, irrigation water supply, and precipitation were combined with the land use profile (agricultural) for input to the EPP. The AFSIRS module determines the irrigation requirements for specific crops in particular locations. When irrigation water supply is insufficient to meet crop requirements, the EPP estimates the potential reduction in total revenues which could result from water shortages.

## 2.5 EPP ASSESSMENT

The EPP model has some theoretical and experimental components. When the USDA, Natural Resources Conservation Service (NRCS) was supporting the Corps in its attempt to estimate the effects of the alternative regulation schedules on agricultural water supply, their staff considered using historical data to develop crop-specific relationships between crop yields and irrigation water shortages. The NRCS reviewed the past 25 years of agricultural water supply data available from the SFWMD and compared this information with historic data on crop yields in south Florida. According to NRCS staff, there was only one drought year during this period (i.e., 1982) when there was a significant shortage of irrigation water in south Florida. During this year, crop yields were significantly lower than other years. However, during this year there was also a freeze that resulted in substantial crop damage. Unfortunately, it was not possible to distinguish the effects of the freeze from the effects of the drought.

The EPP was reviewed to assess its suitability for estimating the NED effects of the LORSS regulation schedule alternatives on agricultural water supply. All five developmental elements illustrated in Figure 2-4 were examined. First, available AFSIRS documents were reviewed to determine its purpose, function, assumptions, strengths, and shortcomings (Thompson and Lynne, 1991). Second, a copy of the modified AFSIRS program for drought impact analysis was obtained from the SFWMD, including input data files, a copy of the computer code, and supporting documentation. Test runs of the modified program were made to evaluate program inputs, function, and outputs. Third, the documentation of the regression analyses that were conducted to develop the functional relationships between simulated $ET_{act}$ and PET, precipitation, and irrigation was reviewed. In addition, SFWMD personnel (Dr. Richard March) involved in developing the EPP were interviewed. Fourth, the spreadsheet prototype of the EPP was examined and tested to evaluate the logic underlying the calculation of the monetary effects of agricultural water shortages. Finally, the draft documentation for the SFWMM was reviewed to determine (1) the outputs from the model used by the EPP and (2) the function of the AFSIRS module within the SFWMM. In addition, the output files from the EPP runs conducted for this investigation were scrutinized to determine how the EPP interacts with the SFWMM.

Based upon our review of the EPP-related materials, the post-processor seems to be a logical and practical approach to a difficult problem, i.e. estimating changes in crop yields and revenues associated with irrigation water shortages. However, there are four categories of issues that qualify the use of the economic post-processor. These issues do not preclude using the EPP to estimate the NED effects of the regulation schedule alternatives on agricultural water supply, but they qualify interpretation of its outputs.

### 2.5.1 Crop Response

The agricultural science that underlies the AFSIRS model is in its infancy. However, the program has been tested by the SFWMD, and calibrated for use in the SFWMM. The Beta coefficients used in the Stewart equation are less evolved and should be considered experimental at this time. Additional research is needed to refine these coefficients. This research could determine the sensitivity of crop yields – and revenue effects – to changes in Beta coefficients. The most useful validation of the drought model would be to test it against empirical data from an actual drought event.

It is unclear whether the yield reductions predicted by the modified AFSIRS model imply crop mortality or, in the case of perennials (e.g., citrus), long-term damage that may affect future crop yields. Crop mortality would probably be limited to severe water shortages, but these events may comprise a significant share of potential revenue effects of water shortages. However, as noted previously, the SFWMD has a policy that commits Lake Okeechobee water supplies sufficient to meet at least one-third of the supplemental irrigation needs of EAA farmers. This minimum irrigation level may prevent extensive crop mortality in the EAA during droughts.

### 2.5.2 Growing Season

The timing of agricultural water supply shortages during the growing season is a critical factor in determining the extent and severity of potential crop losses. The difficulty of applying specific Beta coefficients to particular growth stages was mentioned earlier. In the EPP, the user specifies the start and end months for the growing season for each crop. The simulation of revenue effects is based upon estimates of yield reductions that would result from water shortages during the specified months. If the actual growing seasons are not well aligned with the modeled growing seasons, the accuracy of the simulation could be compromised. The climate of south Florida is problematic in this regard, since it allows more flexibility in planting and harvesting than more northern climates.

There is an additional complication associated with crop rotation. As described previously, it has been estimated that approximately 12.5% of the land under sugarcane cultivation is fallow at any given time. If this is true, that would remove over 60,000 acres of sugarcane cultivation from vulnerability to water shortages. The EPP does not take crop rotation into consideration and therefore may overestimate the potential damages associated with water shortages. Land rotation considerations might also be important for other crops, as well.

### 2.5.3 SFWMM Constraints

The SFWMM provides tremendous analytical power for evaluating the regulation schedule alternatives. However, there are some model-related constraints that affect its use in estimating the economic effects of agricultural water shortages. First, the land use categories in the SFWMM are broader than those used by the EPP. The AFSIRS program is able to accommodate many different crop types and soil varieties not modeled in the SFWMM.

Second, the spatial resolution of the SFWMM model is too coarse to accurately assess the agricultural impacts of the regulation schedule alternatives with great confidence. For example, the SFWMM does not recognize crops other than sugar in the EAA, since none of the 4 square-mile grid cells are dominated by non-sugar crops. In actuality, there are 40,000 acres of non-sugar crops in the EAA.

In addition, the model presents a single value for soil depth in a grid cell. In the EAA, the depth of the soil is a critical factor in assessing the drought vulnerability of sugarcane. A single value (i.e., model node) for an area of 4 square miles may mask significant differences in drought vulnerability for the same crop. Finally, the model must make assumptions about the behavior of farmers in the LOSA during extended dry periods. The ability of farmers to borrow water early in the dry season creates significant uncertainty regarding the timing and effects of water shortages.

### 2.5.4 Prolonged Water Shortages

The EPP calculates crop yield effects on a monthly basis. For shortages of several months duration, the EPP may overestimate the effects on crop yield and revenue because each month is treated independently in the EPP. An example may best explain how an overestimate may occur. If there was a water shortage of 20% during the first month of the shortage, crop yields might be reduced by 10%. If the same shortage persisted to the following month, the crop yield effects would again be calculated at 10%. At the end of the year, the shortage would be tallied by the model as reducing crop yields by 20%. However, a 20% shortage sustained over two months might actually result in less than a 20% reduction in annual yield. Even if the 10% value for the second month was correct, it should probably be discounted (i.e., applied to the 90% of yield remaining after the first month of the shortage). One possible way to address this issue would be to treat shortages with durations of multiple months as a single event, evaluating the aggregate water shortage and applying that percentage to the maximum crop yield.

## 2.6 POTENTIAL NED EFFECTS ON AGRICULTURAL WATER SUPPLY

The NED account should reflect changes in net farm income that are associated with reduced agricultural water supply. According to the SFWMM analyses, the alternative regulation schedules will have different effects on agricultural water supply in the study area and thereby have different impacts on farm incomes. For the LORSS, the determination of NED effects on agricultural water supply requires a four-part process. First, the available water supplies are estimated for each alternative plan. Second, the supplies of the alternative plans are compared to water demand forecasts to identify potential shortfalls in water deliveries. Third, identified shortages are translated into dollar-value reductions in net farm income. Finally, the monetary costs of water supply shortages of each alternative plan are compared to the costs anticipated in the absence of any action (i.e., comparing the with- and without-project conditions) to estimate the net economic effects of the alternative plans. The first two steps have been accomplished in the SFWMM using the model's 31-years of daily simulations. The third and fourth steps are addressed below.

### 2.6.1 Revenue And Income Effects

The economic effects of changes in agricultural water supply can be registered in the NED account if there are resulting changes in either crop damages or land use. No land use effects are anticipated for the Restudy, since implementation of any of the alternative restoration plans is not expected to induce any changes in crop patterns. Therefore, the potential NED effects of changes in agricultural water supply are estimated based upon expected changes in net farm income during drought conditions. The NED account should include the net farm income effects associated with changes in both revenues and production costs resulting from plan implementation.

For sugarcane and non-sugar crops, the cost of crop inputs incurred over the course of the growing season would not change during shortages. The potential income effects of water shortages would therefore be derived from changes in harvesting and transportation (to processing facilities) costs. For sugarcane, harvesting and transportation in the EAA are conducted by the sugar mills, which then deduct these costs from their payments to the farmers for the cane. Sugarcane harvesting costs would not be expected to change during shortages for two reasons. First, while shortages would reduce sugarcane yields, it is assumed that the SFWMD will provide sufficient irrigation water supplies to avoid crop mortality. As a result, the same area would be harvested during shortages as during non-shortage periods, since sugarcane is drought-tolerant. Second, since sugarcane harvesting is entirely mechanized, the combines would harvest the same areas during shortages with costs identical to non-shortage periods.

Under water stress, sugarcane yields in terms of biomass are reduced. Consequently, reductions in transportation costs to the sugar mills are expected. Given the relatively small shortage-induced changes in transportation costs anticipated for sugarcane and the inherent difficulty in quantifying them, it can be assumed for practical purposes that changes in farm revenues are approximately equal to changes in farm income. However, the exclusion of changes in sugarcane transportation costs during shortages may slightly exaggerate reductions in farm income associated with water shortages.

For vegetables and other non-sugar crops in the EAA, the assumption that changes in revenue equal changes in income is valid for other reasons. In the EAA, non-sugar crops such as rice, sod, and truck vegetables are raised by sugar farmers as supplemental crops. Based upon interviews with experts on EAA farm practices, it appears that during shortages, these crops would have irrigation priority over sugarcane. These crops are high-value relative to cane, and they are much more vulnerable to water shortages.

In the LEC, the assumption that changes in revenues would equal changes in income would not be applicable to non-sugar crops (row crops, citrus, etc). There would be some reductions in harvesting costs, as well as reductions in transportation costs. However, most of the effects of agricultural water shortages in the LEC are associated with urban landscaping and golf land uses, not commercial agriculture. Consequently, the assumption that changes in revenues equal changes in farm income remains valid for agriculture in the LEC, as well as in the EAA.

### 2.6.2 Crop Prices

Crop prices contained in the EPP come from a variety of sources. Representative prices for agricultural crops (rice, sugar, sod, tomatoes, citrus, avocado, and nurseries) were obtained from the Florida Agricultural Statistics Service (FASS). Representative values for the remaining categories (urban turf and golf turf) were derived from the 1992 Water Shortage Economic Impact Model study conducted for the SFWMD. They are better described as willingness-to-pay values (for green lawns and fairways), rather than market prices.

Corps planning guidance specifies that normalized prices developed by the U.S. Department of Agriculture (USDA) are to be used in water resources planning investigations whenever possible. If normalized prices are not available for a particular crop, average prices for a three-year period are to be used. As indicated in Table 2-6, the USDA normalized prices for 1996 include three of the EPP crop categories: sugarcane, rice, and citrus (oranges and grapefruit). The prices for rice and citrus were used to modify the EPP outputs. However, the normalized price for sugar refers to raw sugar, not sugarcane. Consequently, a three-year average price for sugarcane (1994-1996) was used to modify the EPP outputs. The price used for citrus was an average of the orange and grapefruit prices. For fall and spring tomatoes and avocados, three-year averages (1995-1997) were calculated using FASS data. Sod prices were problematic, since there is very little data available. The sod prices used in the EPP were based on values developed for the SFWMD (1993) in consultation with University of Florida Professor Haydu, a recognized expert in sod cultivation. No modifications were made to the nursery prices or the willingness-to-pay values for urban turf and golf turf.

**TABLE 2-6**
**UNIT PRICES USED TO UPDATE EPP OUTPUT TO 1996 VALUES ($)**

| Crop | Units | EPP Unit Prices | Normalized Prices | Unit Prices Used | Comment |
|---|---|---|---|---|---|
| Sugarcane | Ton | $31.12 | 30.82 | $30.53 | 3-year average |
| Rice | Cwt. | $10.00 | $6.98 | $ 6.98 | normalized |
| Sod | Acre | $3,600.00 | | $960 | SFWMD values (1993) |
| Tomatoes – fall | Bushel | $9.35 | | $8.27 | 3-year average |
| Tomatoes–spring | Bushel | $9.35 | | $7.29 | 3-year average |
| Citrus | Acre | $4.99-6.63 | Oranges - $6.37 Grapefruit - $5.58 | $5.98 | average of normalized |
| Avocado | Bushel | $1.74-41.80 | | $14.50 | 3-year average |
| Urban | Acre | $3,600.00 | | $3,600.00 | No Change |
| Golf | Acre | $182.00 | | $182.00 | No Change |
| Nursery | Acre | $7,597.00 | | $7,597.00 | No Change |

Sources: Normalized Prices: U.S. Department of Agriculture. 1996.
Market Prices: Florida Agricultural Statistics Service. 1997.

## 2.7 EVALUATION OF ALTERNATIVE REGULATION SCHEDULES

Evaluation of the effects of the alternative regulation schedules on agricultural water supply and revenues includes two principal components. First, the effects on agriculture in the EAA and LEC are estimated using the EPP. Second, the effects on agriculture in the Caloosahatchee and St. Lucie basins are estimated separately, using outputs from the SFWMM. These two sets of effects are discussed below.

### 2.7.1 Agricultural Water Supply in the EAA and LEC

Table 2-7 contains the SFWMM-simulated revenue (and income) effects on agriculture in the EAA and LEC associated with the current regulation schedule and the three alternative schedules under the 1990 (current) and 2010 (future) scenarios. The values contained in this table represent the values of unmet demand for agricultural water supply, translated into income losses using the EPP. The value of unmet demand is defined as the difference between maximum possible yields under unconstrained water conditions and the yields predicted by the model for each regulation schedule. Therefore, the higher the value of unmet listed in the table, the greater the reduction in potential yields (and revenue losses) imposed by each alternative. The positive values shown in the table for unmet demand under existing conditions (Run 25) indicates that existing water shortages currently result in reduced crop yields. Alternative regulation schedules with higher unmet demands than existing conditions indicate increased crop losses (i.e., worsened conditions). Alternative regulation schedules with lower unmet demands than existing conditions indicated decreased crop losses (i.e., improved conditions).

The values in the table represent simulated income losses from agricultural water supply shortages during the 31-year simulation period. They include the estimated demands not met for urban (turf) and golf (turf) land uses, as well as agricultural crops. The average annual values are arithmetic averages of total income effects distributed over the 31 years. The 1990 and 2010 scenarios represent existing and future conditions, respectively. As indicated in this table, two of the alternative regulation schedules (Run22AZE and COEREC) result in greater unmet demand for agricultural water than the current schedule. The other two alternatives (HSMREC and WSE) are expected to meet agricultural water demands more effectively than the current schedule.

Table 2-7 indicates that the value of unmet agricultural water demand is expected to increase significantly between 1990 and 2010 for the with- and without-project conditions. As explained in Chapter 1, there are differences in the SFWMM's 1990 and 2010 scenarios that exceed the substantial socioeconomic and land use changes expected to occur in south Florida during the coming decades. Therefore, it is not possible to estimate the effects of these changes. However, comparison of the 1990 and 2010 results in Table 2-7 clearly reflects the additional stress on the regional water management system that is expected to be manifested by 2010. Much of this stress can be attributed to socioeconomic and land use changes.

# TABLE 2-7
## VALUE OF UNMET DEMAND FOR AGRICULTURAL WATER SUPPLY
## EAA AND LEC
## 1990, 2010 SCENARIOS
## ($1996)

| Scenario | Area | Total 1990 | Average Annual 1990 | Total 2010 | Average Annual 2010 |
|---|---|---|---|---|---|
| Run25 | EAA | $24,283,348 | $783,334 | $122,268,803 | $3,944,155 |
| Run25 | SA1 | $30,132,140 | $972,005 | $48,420,694 | $1,561,958 |
| Run25 | SA2 | $22,753,569 | $733,986 | $44,189,265 | $1,425,460 |
| Run25 | SA3 | $15,142,583 | $488,470 | $6,762,927 | $218,159 |
| Run25 | SA4 | $6,188,237 | $199,621 | $89,104,984 | $2,874,354 |
| **Run25** | **Total** | **$98,499,877** | **$3,177,415** | **$310,746,673** | **$10,024,086** |
| Run22AZE | EAA | $35,501,505 | $1,145,210 | $158,980,731 | $5,128,411 |
| Run22AZE | SA1 | $30,132,140 | $972,005 | $47,985,614 | $1,547,923 |
| Run22AZE | SA2 | $20,445,349 | $659,527 | $43,321,521 | $1,397,468 |
| Run22AZE | SA3 | $15,142,583 | $488,470 | $10,503,236 | $338,814 |
| Run22AZE | SA4 | $6,188,237 | $199,621 | $90,088,062 | $2,906,067 |
| **Run22AZE** | **Total** | **$107,409,814** | **$3,464,833** | **$350,879,165** | **$11,318,683** |
| COEREC | EAA | $26,782,473 | $863,951 | $136,836,712 | $4,414,087 |
| COEREC | SA1 | $30,132,140 | $972,005 | $48,446,703 | $1,562,797 |
| COEREC | SA2 | $20,459,159 | $659,973 | $40,513,417 | $1,306,884 |
| COEREC | SA3 | $15,142,583 | $488,470 | $10,461,824 | $337,478 |
| COEREC | SA4 | $6,188,237 | $199,621 | $90,228,600 | $2,910,600 |
| **COEREC** | **Total** | **$98,704,592** | **$3,184,019** | **$326,487,256** | **$10,531,847** |
| HSMREC | EAA | $9,240,759 | $298,089 | $105,739,800 | $3,410,961 |
| HSMREC | SA1 | $30,132,140 | $972,005 | $48,179,588 | $1,554,180 |
| HSMREC | SA2 | $22,753,569 | $733,986 | $40,448,479 | $1,304,790 |
| HSMREC | SA3 | $14,948,745 | $482,218 | $6,051,575 | $195,212 |
| HSMREC | SA4 | $6,188,237 | $199,621 | $90,641,056 | $2,923,905 |
| **HSMREC** | **Total** | **$83,263,450** | **$2,685,918** | **$291,060,498** | **$9,389,048** |
| WSE | EAA | $15,114,090 | $487,551 | $120,000,943 | $3,870,998 |
| WSE | SA1 | $30,132,140 | $972,005 | $48,484,903 | $1,564,029 |
| WSE | SA2 | $20,459,159 | $659,973 | $40,513,417 | $1,306,884 |
| WSE | SA3 | $14,948,745 | $482,218 | $6,804,339 | $219,495 |
| WSE | SA4 | $6,188,237 | $199,621 | $89,117,219 | $2,874,749 |
| **WSE** | **Total** | **$86,842,237** | **$2,801,367** | **$304,920,821** | **$9,836,156** |

Table 2-8 shows the NED effects of the four alternative regulation schedules on agricultural water supply under current (1990) and future (2010) with-project conditions. The values in this table are the differences between the values in Table 2-7 for the without-project conditions (Run25) and four alternative regulation schedules. Negative numbers in Table 2-8 indicate that the alternatives have unmet agricultural water demands that exceed those associated with the current regulation schedule. For example, as shown in Table 2-7, the 2010 average annual value of unmet demand associated with Run22AZE is $11,318,683. The similar value for Run25 is $10,024,068. As indicated the second column in Table 2-8, the difference between the with- and without-project future conditions is $1,294,597.

**TABLE 2-8**
**NED EFFECTS**
**EAA AND LEC AGRICULTURAL WATER SUPPLY**
**1990, 2010($1996)**

| Alternative | Scenario | Total Net Revenue Effect | Net Annual Revenue Effect | % Change in Revenue Effects | Rank |
|---|---|---|---|---|---|
| Run22AZE | 1990 | -$8,909,937 | -$287,417 | -9.0% | 4 |
| COEREC | 1990 | -$204,715 | -$6,604 | -.2% | 3 |
| HSMREC | 1990 | +$15,236,427 | +$491,498 | +15.5% | 1 |
| WSE | 1990 | +$11,657,640 | +$376,053 | +11.8% | 2 |
| Run22AZE | 2010 | -$40,132,492 | -$1,294,597 | -12.9% | 4 |
| COEREC | 2010 | -$15,740,583 | -$507,761 | -5.1% | 3 |
| HSMREC | 2010 | +$19,686,175 | +$635,038 | +6.3% | 1 |
| WSE | 2010 | +$5,825,852 | +$187,931 | +1.9% | 2 |

As indicated in Table 2-8 for the 1990 and 2010 scenarios, two alternatives (HSMREC and WSE) are expected to generate fewer unmet agricultural water supply demands than the current schedule, as evidenced by the positive value. Under both scenarios, the HSMREC regulation schedule is anticipated to have fewer unmet agricultural demands than the WSE schedule. The other two alternatives (Run22AZE and COEREC) are expected to have more unmet demands than the current schedule. Under the 1990 and 2010 scenarios Run22AZE has expected income losses significantly higher than those of COEREC. The comparison of the 1990 and 2010 estimates in Table 2-8 indicates that the differences between the alternative regulation schedules would increase over time. This suggests that the regional water management system would become more sensitive to relatively small operational changes, such as the LORSS alternatives, as the system becomes more stressed due in part of the socioeconomic and land use changes described above.

### 2.7.2 Agricultural Water Supply in the St. Lucie and Caloosahatchee Basins

While it would be desirable to estimate the income effects of the irrigation demands not met for the Caloosahatchee and St. Lucie basins, this is problematic. The EPP does not address the Caloosahatchee and St. Lucie basins, but the SFWMM does generate information which is relevant to the evaluation of the alternative regulation schedules. The EPP was designed for evaluating irrigated agriculture in the EAA and in the LEC. It is directly dependent on the SFWMM for critical inputs, including PET, precipitation, and net irrigation. While the Caloosahatchee and St. Lucie basins are not included in the SFWMM grid cell network, these basins are incorporated in the SFWMM as single model nodes, much like individual grid cells. These basins are important components of the regional water management system, since they have water demands – particularly for agriculture – that draw upon the lake's water resources.

The SFWMM runs conducted for the LORSS simulated irrigation water demands and demands not met (in acre-feet and as percentages) for the LOSA, which includes the Caloosahatchee and St. Lucie basins. Since the EPP does not estimate revenue effects of agricultural water shortages for the Caloosahatchee or St. Lucie basins, these two measures (irrigation water demands and demands not met) provide the best insight to the agricultural water supply effects of the regulation schedule alternatives. Table 2-9 presents 1990 and 2010 simulated water demands and demands not met for the non-EAA portion of the LOSA. The Caloosahatchee or St. Lucie basins are contained in the Other LOSA Area category (as SFWMM designations C-43 and C-44), along with other non-EAA portions of the LOSA. As indicated in Table 2-9, the simulated 2010 percentages of demands not met for the non-EAA portion of the LOSA are: 17% (Run25), 21% (Run22AZE), 18% (COEREC), 14% (HSMREC), and 17% (WSE).

**TABLE 2-9**
**SIMULATED AGRICULTURAL DEMANDS AND DEMANDS NOT MET**
**NON-EAA PORTION OF THE LOSA**
**1990 AND 2010 SCENARIOS**

| Regulation Schedule | Year | Demands Met (acre-feet) | Demand Not Met (acre-feet) | % Demands Not Met | Rank |
|---|---|---|---|---|---|
| Run25 | 1990 | 5389 | 329 | 6% | n.a. |
| Run22AZE | 1990 | 5325 | 443 | 8% | 4 |
| COEREC | 1990 | 5478 | 169 | 6% | 2 (tied) |
| HSMREC | 1990 | 5375 | 352 | 3% | 1 |
| WSE | 1990 | 5401 | 325 | 6% | 2 (tied) |
| Run25 | 2010 | 7000 | 1384 | 17% | n.a. |
| Run22AZE | 2010 | 6689 | 1779 | 21% | 4 |
| COEREC | 2010 | 6877 | 1523 | 18% | 3 |
| HSMREC | 2010 | 7145 | 1206 | 14% | 1 |
| WSE | 2010 | 6939 | 1460 | 17% | 2 |

Comparison of the four alternative regulation schedules with the current schedule (Run25) suggests two conclusions regarding the potential effects of the alternative regulation schedules on agricultural water supply in the Caloosahatchee and St. Lucie basins. First, two of the schedules, Run22AZE and COEREC, are expected to result in higher levels of agricultural water demands not met in these basins. Second, of the two schedules that are expected to have lower demands not met in these basin (HSMREC and WSE), the HSMREC schedule is anticipated to have significantly lower agricultural demands not met. For both sets of alternative regulation schedules, the changes in irrigation demands not met would have economic consequences.

Although it is not possible to quantify these consequences at this time, the hydrologic indicators suggest the relative performance of the alternative plans in terms of agricultural water supply in these two basins.

In sum, the HSMREC alternative is expected to have the best performance among the alternative regulation schedules in terms of agricultural water supply. For the EAA and LEC, this alternative showed the most improvement over the existing schedule (Run25) under the 1990 and 2010 scenarios. In addition, for the Caloosahatchee and St. Lucie basins, HSMREC was ranked first under the 1990 and 2010 scenarios in terms of agricultural water demands not met. In terms of agricultural water supply for the LEC and EAA and for the two basins, the HSMREC alternative is followed by WSE, COEREC, and Run22AZE.

# 3. MUNICIPAL AND INDUSTRIAL WATER SUPPLY

## OVERVIEW

The hydrologic effects of the alternative regulation schedules also have implications for municipal and industrial (M&I) water supply. In the LORSS study area, most of the M&I water use is in the three service areas of the LEC. If water demands exceed supplies, shortages may result, and cutbacks may be imposed by the SFWMD.

As outlined in the previous chapter, the SFWMD's Water Shortage Plan curtails water use in south Florida using a four-phase progression of increasingly severe restrictions: Phase I (Moderate), Phase II (Severe), Phase III (Extreme), and Phase IV (Critical). Cutbacks in the first two phases are primarily voluntary. In the more severe shortages (Phases III and IV), mandatory use restrictions are imposed. The cutbacks imposed by the plan affect residential, commercial, and industrial water users. The restrictions on M&I water use during shortages have associated opportunity costs. The economic impacts of the alternative regulation schedules are the differences between the without-project costs associated with the current regulation schedule and the with-project costs associated with the alternative regulation schedules.

Whether voluntary or mandatory, shortages of M&I water supply – like agricultural shortages – can have significant economic implications. There may be direct costs associated with active conservation measures (i.e., reducing water use during shortages), particularly for residential and commercial water users who may experience opportunity costs as a result of reduced supplies, affecting water-related activities such as watering lawns, washing cars, etc. If shortages are frequent, there may be M&I costs associated with developing new sources of supply, increased treatment costs, and/or instituting passive water conservation measures, such as low-flow plumbing fixtures, which reduce day-to-day water use. There may also be secondary effects, such as the utility revenue losses that are experienced when M&I users reduce consumption during shortages.

## 3.1 CONCEPTUAL APPROACHES TO M&I WATER SUPPLY EVALUATION

The alternative regulation schedules could potentially affect the frequency, severity, and duration of M&I water shortages. The conceptual basis for evaluating the economic effects of changes in M&I water supply associated with alternative plans is society's willingness to pay (WTP) for the increase in the value of goods and services attributable to the water supplied. Corps of Engineers planning guidance stipulates that where the price of water reflects its marginal cost, the price should be used to calculate WTP for water supply – in this case, for the amount of water foregone in the supply shortfall. In the absence of such direct measures of WTP, the effects of water supply plans should instead be measured by the least cost alternative (LCA) to replace the shortfall in supply.

The LCA method is widely used in the Corps, given the difficulty of directly measuring WTP for water supply. However, for the LORSS, WTP was selected as the primary approach to estimate M&I water supply impacts for two principal reasons. The first reason concerns how M&I water is supplied to users in the LEC. In the LEC service areas, M&I water is supplied to users by local utilities. The utilities draw upon local water resources – primarily groundwater – to meet their customers' needs. When shortages occur during prolonged dry periods, the utilities can draw upon the regional water supply system to augment their supplies or they can develop supplemental sources of water. These supplemental sources include: (1) developing additional well fields, (2) instituting more aggressive water conservation measures, or (3) tapping the deep Floridan aquifer, treating this brackish water with reverse osmosis and blending it with water from other sources.

The ability of local utilities to draw upon the regional system or tap local resources for alternative sources of supply is not a practical alternative, however. The LCA for a utility during a particular shortage would depend on the condition of the regional system. If the shortage was localized, a utility might be able to draw freely upon the regional system, and not need to develop supplemental sources of supply. However, if the water shortage was regional in nature, then access to regional water supplies would be limited by widespread shortages and institutional restrictions, limiting the ability of local water utilities to develop alternative sources of supply.

Table 3-1 presents a summary of recommendations prepared by the SFWMD for the Draft Lower East Coast Water Supply Master Plan (1997). These recommendations illustrate the type of water supply measures that are considered to augment regional and local water supplies. The SFWMD has prepared preliminary cost estimates for some of these measures. Since no capacity estimates were prepared however, estimates of unit cost are not available. In addition, the scale of the measures and the uncertainty of their costs make LCA-based estimation of M&I water supply effects impractical for the LORSS study. Nevertheless, this information provides a context for evaluating the output of the WTP approach.

The second reason that WTP was selected as the principal approach for calculating the economic effects of M&I water shortages is based on ability of the EPP to estimate M&I water supply effects of the alternative regulation schedules. The SFWMM runs conducted for this investigation compared M&I water supply with demand. This requires a disaggregation/distribution procedure that accounts for spatial and sectoral uses, as well as groundwater pumpage. In its 31-year simulations, the SFWMM estimated the location, severity, and duration of M&I water supply shortages. It also simulated the frequency and phase of water shortage declarations based on: (1) Lake Okeechobee levels and (2) salinity intrusion into coastal aquifers (estimated using water surface elevations in monitoring wells). These outputs from the SFWMM were then input to the EPP to calculate the economic effects of changes in the level of M&I water supply for each alternative regulation schedule.

For each of the water shortage phases, the EPP estimates dollar damages from cutbacks based on the WTP (in dollars per 1000 gallons) of regional M&I water consumers. The SFWMD developed these public water supply loss values on the basis of a 1992 survey of M&I water users in south Florida. The survey, which was conducted following a regional water shortages in 1989 and 1992, queried respondents' WTP for water under Phase III and Phase IV reductions. SFWMD staff economists adjusted these values to estimate WTP values for Phases I and II and inflated the WTP values for all four water shortage phases to reflect consumer surplus. The resultant 1992 WTP values were updated to 1996 price levels. The water supply shortfalls in a given shortage phase are multiplied by the WTP associated with that phase to determine the economic costs of the shortage. The values of the unmet water demands during M&I shortages are the basis for comparing the alternative regulation schedules against the without-project future conditions.

**TABLE 3-1**
**RECOMMENDATIONS OF THE**
**DRAFT LOWER EAST COAST WATER SUPPLY MASTER PLAN**

| |
|---|
| **Regional:** |
| Water Resource Partnerships/Basin Level Planning |
| Alternative Water Supply Development |
| Regional Storage Recommendation |
| Modifications to SFWMD Regulatory Program: Permit Duration |
| Modifications to SFWMD Regulatory Program: Level of Certainty |
| Saltwater Intrusion Management |
| Floridan Aquifer Regional Model Development |
| Aquifer Storage and Recovery Working Group |
| East Coast Buffer/Water Preserve Areas |
| Lake Okeechobee Regulation Schedule |
| Funding Strategy |
| **Northern Palm Beach County:** |
| North Palm Beach County Water Management Plan |
| L-8 Option |
| Discharges to Lake Worth Lagoon via C-17 |
| **LEC-SA1:** |
| Southeastern Palm Beach County Integrated Water Resource Plan |
| Regional Groundwater Aquifer ASR Pilot Project |
| Southeastern Lake Worth Drainage District Storage Feasibility Analysis |
| Site 1 Reservoir |
| Utility Well Field Expansion |
| **LEC-SA2:** |
| Coastal Broward County Integrated Water Resource Management Plan |
| Broward County Secondary Canals Recharge Network |
| Utility Well Field Expansion |
| **LEC-SA3:** |
| South Dade County Integrated Water Resource Management Plan |
| C-4 Structures |
| Utility Aquifer Storage and Recovery |

## 3.2 EVALUATION OF ALTERNATIVE REGULATION SCHEDULES

The NED costs of reductions in M&I water supply are the changes in the quantity or price of delivered water over time between the with- and without-project conditions. The SFWMM runs indicate that there will be unmet demand for M&I water supply under both existing and future conditions for the current regulation schedule and the alternative regulation schedules. Table 3-2 summarizes the economic value of unmet demand for M&I water supply associated with the current regulation schedule and the four alternative schedules under the 1990 and 2010 scenarios. As was the case with agricultural water supply, the larger the value, the greater the losses/negative effects associated with water shortages. Alternative regulation schedules with values larger than the without project condition will worsen M&I water supply shortages. Alternatives with lower values than the without project condition represent improvements (i.e., reductions in unmet demand).

Average annual costs are included in this table, which were calculated as the arithmetic average over the 31-year simulation period. The values in Table 3-2 represent the simulated dollar amounts that M&I water users are willing to pay for water they want but do not receive during water shortages.

The net effects of the four alternative regulation schedules on M&I water supply are shown in Table 3-3 under the 1990 and 2010 scenarios. Net effects were calculated as the difference between the value of unmet demand under without-project (Run25) conditions and with-project conditions (i.e., Run22AZE, COEREC, HSMREC, and WSE). These differences represent the NED effects of the alternative regulation schedules. Negative values indicate that the alternative regulation schedule has greater unmet M&I water demands than the current regulation schedule. As indicated in Table 3-3, under the 1990 and 2010 scenarios the HSMREC alternative is expected to have the best performance among the alternative regulation schedules in terms of M&I water supply, followed by the WSE, COEREC, and Run22AZE schedules.

The 2010 values for unmet M&I water demands presented in Table 3-2 bear some qualification. As indicated in Chapter I, the 2010 base scenario in the SFWMM assumes that the new (i.e., since 1990) M&I demands in the LEC are met by withdrawing more groundwater from existing wellfields. Many of these wellfields are located near the coast and are sensitive to salinity intrusion. Additional withdrawals from these wellfields could induce seawater intrusion into coastal aquifers. For this reason, SFWMD policy encourages the location of new wellfields sufficiently inland to protect coastal aquifers. The modeled 2010 scenario is therefore not consistent with this policy. This is a simplifying assumption in the model that probably results in overstatement of M&I water shortage impacts under the 2010 scenarios for the with- and without-project conditions. When the SFWMM assigns the new demands to the existing wellfields, there is a consequent increase in the number of simulated M&I shortages based on the inflated estimates of drawdown at these wellfields.

# TABLE 3-2
# VALUE OF UNMET DEMAND FOR M&I WATER SUPPLY (1990, 2010)
# ($1996)

| Scenario | Area | Total M&I 1990 | Average Annual M&I 1990 | Total M&I 2010 | Average Annual M&I 2010 |
|---|---|---|---|---|---|
| Run25 | SA1 | $84,579,130 | $2,728,359 | $164,580,000 | $5,309,033 |
| Run25 | SA2 | $136,583,652 | $4,405,924 | $230,198,348 | $7,425,753 |
| Run25 | SA3 | $178,187,043 | $5,747,969 | $149,311,217 | $4,816,491 |
| Run25 | SA4 | $32,781,478 | $1,057,467 | $978,496,435 | $31,564,401 |
| **Run25** | **Total** | $432,131,303 | $13,939,719 | $1,522,586,000 | $49,115,678 |
| Run22AZE | SA1 | $86,107,478 | $2,777,660 | $167,662,696 | $5,408,474 |
| Run22AZE | SA2 | $136,501,130 | $4,403,263 | $236,551,391 | $7,630,690 |
| Run22AZE | SA3 | $181,639,391 | $5,859,335 | $176,126,261 | $5,681,492 |
| Run22AZE | SA4 | $33,121,739 | $1,068,443 | $980,439,652 | $31,627,085 |
| **Run22AZE** | **Total** | $437,369,738 | $14,108,701 | $1,560,780,000 | $50,347,741 |
| COEREC | SA1 | $84,579,130 | $2,728,359 | $166,214,609 | $5,361,762 |
| COEREC | SA2 | $139,168,957 | $4,489,322 | $226,266,696 | $7,298,926 |
| COEREC | SA3 | $178,187,043 | $5,747,969 | $162,746,435 | $5,249,885 |
| COEREC | SA4 | $32,781,478 | $1,057,467 | $988,479,304 | $31,886,429 |
| **COEREC** | **Total** | $434,716,608 | $14,023,117 | $1,543,707,044 | $49,797,002 |
| HSMREC | SA1 | $84,579,130 | $2,728,359 | $157,882,174 | $5,092,974 |
| HSMREC | SA2 | $136,583,652 | $4,405,924 | $217,798,609 | $7,025,762 |
| HSMREC | SA3 | $170,808,696 | $5,509,958 | $132,992,261 | $4,290,073 |
| HSMREC | SA4 | $32,781,478 | $1,057,467 | $989,008,348 | $31,903,496 |
| **HSMREC** | **Total** | $424,752,956 | $13,701,708 | $1,497,681,392 | $48,312,305 |
| WSE | SA1 | $86,107,478 | $2,777,660 | $167,835,652 | $5,414,053 |
| WSE | SA2 | $141,463,739 | $4,563,346 | $226,266,696 | $7,298,926 |
| WSE | SA3 | $174,261,043 | $5,621,324 | $157,219,739 | $5,071,604 |
| WSE | SA4 | $33,121,739 | $1,068,443 | $987,717,391 | $31,861,851 |
| **WSE** | **Total** | $434,953,999 | $14,030,773 | $1,539,039,478 | $49,646,434 |

## TABLE 3-3
## M&I WATER SUPPLY EFFECTS
## ALTERNATIVE REGULATION SCHEDULES
## 1990 AND 2010 SCENARIOS
## ($1996)

| Alternative | Scenario | Total NED Impacts of Alternatives | Annual NED Impacts | Percent Change In Value of Unmet Demand | Rank |
|---|---|---|---|---|---|
| Run22AZE | 1990 | -$5,238,435 | -$168,982 | -1.2% | 4 |
| COEREC | 1990 | -$2,585,304 | -$83,398 | -0.6% | 2 |
| HSMREC | 1990 | +$7,378,348 | +$238,011 | +1.7% | 1 |
| WSE | 1990 | -$2,822,696 | -$91,056 | -0.7% | 3 |
| | | | | | |
| Run22AZE | 2010 | -$38,194,000 | -$1,232,065 | -2.5% | 4 |
| COEREC | 2010 | -$21,121,043 | -$681,324 | -1.4% | 3 |
| HSMREC | 2010 | +$24,904,609 | +$803,374 | +1.6% | 1 |
| WSE | 2010 | -$16,453,478 | -$530,757 | -1.1% | 2 |

# 4. COMMERCIAL NAVIGATION

## OVERVIEW

The purpose of this chapter is to evaluate the potential impact of the alternative regulation schedules on commercial navigation in the Lake Okeechobee Waterway, which consists of the lake, the Caloosahatchee River, and the St. Lucie Canal. The alternative regulation schedules were designed to have different effects on water levels in Lake Okeechobee. The potential impacts on commercial navigation are based on associated changes in the frequency of extremely low lake levels. If some portion of the commercial vessel fleet draws all of the waterway's authorized depths, reduced lake stages may prohibit passage of those vessels, delay their passage, or induce reductions in their loads. These impacts could have economic impacts on the shippers or the commodities they are transporting.

Even at the lowest lake levels, there are expected to be significant differences between alternative regulation schedules. As shown in Table 4-1, the SFWMM runs for the LORSS simulated undesirable low lake levels for Lake Okeechobee. In the 31-year simulations for the 2010 scenario, the model estimated that the Run25 schedule (i.e., without project condition) would result in three instances in which lake stages would be below 11 feet NGVD for more than 100 days. Two of the alternative regulation schedules (Run22AZE and WSE) are expected to have more of these low-water events under the 2010 scenario; one regulation schedule (COEREC) is expected to have similar performance to Run25; and one (HSMREC) is expected to have fewer of these events. As in the preceding estimation of water supply effects, the assessment of commercial navigation impacts will be based on expected differences between the current regulation schedule (Run25) and the four alternative schedules.

**TABLE 4-1**
**SIMULATED NUMBER OF UNDESIRABLE LOW LAKE STAGE EVENTS**
**1990 AND 2010 SCENARIOS**

| | Scenario | Run25 | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|---|---|
| Number of Times Stage < 12 ft for > 1 year | 1990 | 1 | 1 | 1 | 1 | 1 |
| | 2010 | 1 | 1 | 1 | 1 | 1 |
| Number of Times Stage < 11 ft for > 100 days | 1990 | 2 | 2 | 2 | 1 | 2 |
| | 2010 | 3 | 5 | 3 | 2 | 4 |

## 4.1 PHYSICAL FEATURES OF THE WATERWAY

The Lake Okeechobee Waterway was completed in 1937 and includes 154 miles of navigation channel and five lock structures linking Stuart on the Atlantic Ocean with Ft. Myers on the Gulf of Mexico. As indicated in Figure 4-1, the five lock and dams (from west to east) are: W.P. Franklin, Ortona, and Moore Haven on the Caloosahatchee River; and Port Mayaca and St. Lucie on the St. Lucie Canal. The Moore Haven and Port Mayaca locks connect the lake with the Caloosahatchee River and St. Lucie Canal, respectively. Using the locks to designate waterway reaches, the channel dimensions of the Lake Okeechobee Waterway at lake elevation 12.56 feet NGVD are presented in Table 4-2. As indicated in this table – and Figure 4-1 – there are two routes from Port Mayaca on the lake's eastern shore to Clewiston on the southwestern shore. Route 1, which cuts across the lake, has a deeper channel (8 feet). Route 2, which hugs the eastern shoreline, is known as the rim canal. This route has a shallower channel (6 feet) and is longer than Route 1, but it is more sheltered. The shallow depths of the lake can induce severe wave conditions on the lake which are disproportionate to wind velocities. During inclement weather, the rim canal is the preferred route between Clewiston and Port Mayaca.

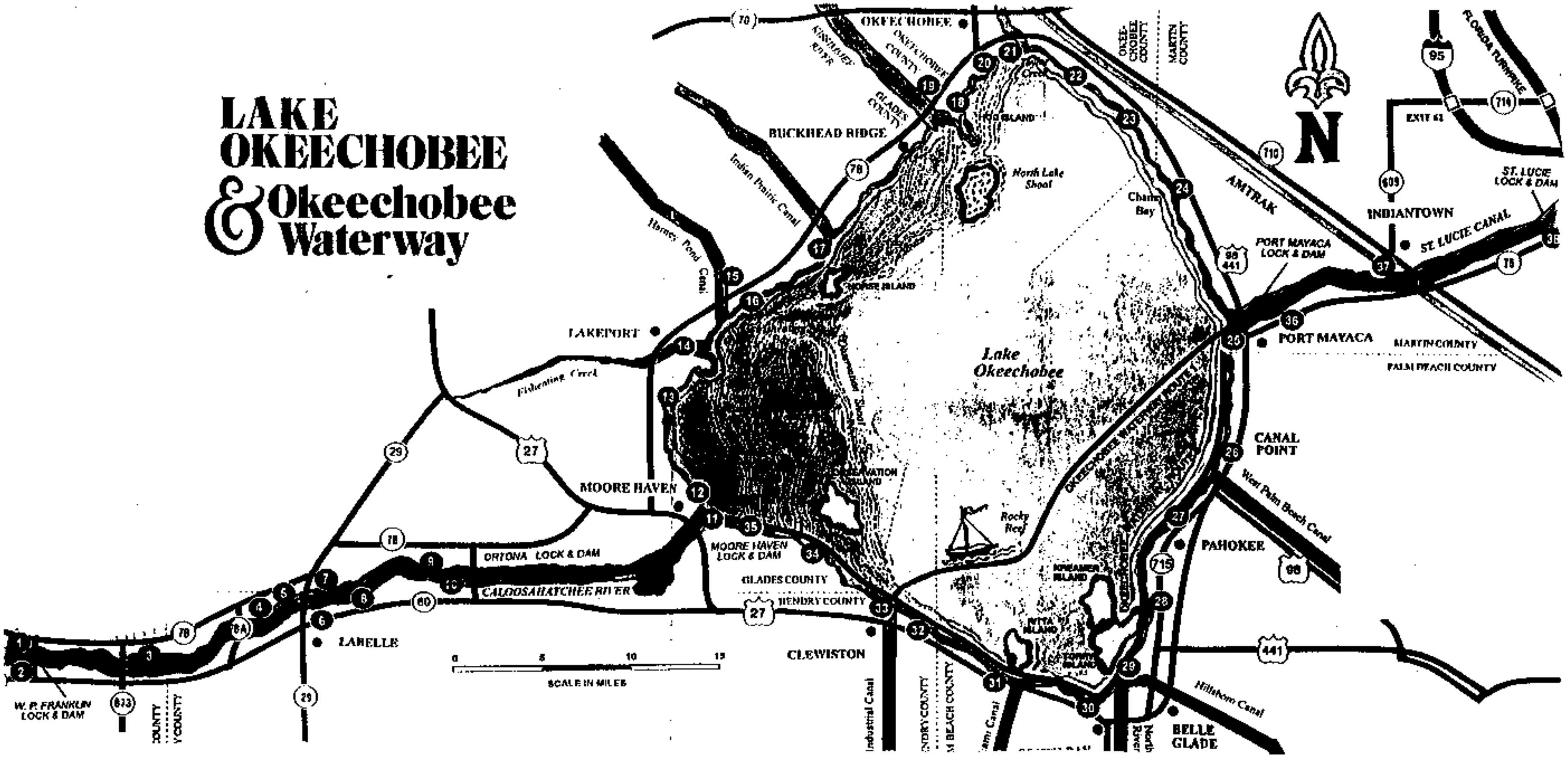
**TABLE 4-2**
**CHANNEL DIMENSIONS**
**LAKE OKEECHOBEE WATERWAY**

| Waterway Reach | Channel Dimensions | Length of Reach |
|---|---|---|
| Atlantic Intracoastal to St. Lucie Lock | outside project limits | 15.1 miles |
| St. Lucie Lock to Port Mayaca Lock | 8' x 100' | 23.7 miles |
| Port Mayaca Lock to Clewiston (rim canal) | 6' x 100' | 39.5 miles |
| Port Mayaca Lock to Clewiston (open lake) | 8' x 100' | 28.5 miles |
| Clewiston to Moore Haven Lock (rim canal) | 8' x 80' | 10.5 miles |
| Moore Haven Lock to Ortona Lock | 8' x 90' | 15.5 miles |
| Ortona Lock to W.P. Franklin Lock | 8' x 90' | 27.9 miles |
| W.P. Franklin to Gulf Intracoastal | outside project limits | 33.2 miles |
| | TOTAL | 154.4 miles (open lake)<br>165.4 miles (rim canal) |

The Lake Okeechobee Waterway has an authorized project depth of eight feet based upon a lake stage of 12.56 feet NGVD. The depth of this waterway is controlled by managing lake levels - no maintenance dredging is conducted for this waterway. Consequently, lake levels above (or below) 12.56 feet NGVD will result in a corresponding increase (or decrease) in channel depths. So, for example, at a lake level of 11 feet NGVD the channel depth would be approximately 6.5 feet NGVD in the open lake and 4.5 feet NGVD in the rim canal.

There are five locks on the Lake Okeechobee Waterway, all operated by the Corps of Engineers. Three locks are located on the Caloosahatchee River: the Moore Haven Lock on Lake Okeechobee (R.M. 78), the W.P. Franklin Lock and Dam (R.M. 122) between Tice and La Belle, and the Ortona Lock (R.M. 93.6). In addition, there are two locks on the St. Lucie Canal: the Port Mayaca Lock on the lake's eastern shore (R.M. 38.5) and the St. Lucie Lock (R.M. 15.3) near I-95.

Table 4-3 presents the lock dimensions for the five locks and dams on the Lake Okeechobee Waterway. The elevation of the bottom of Lake Okeechobee is approximately equal to sea level. As a result, with a lake elevation at 15.5 feet NGVD, the Caloosahatchee and St. Lucie locks




# FIGURE 4-1
# LAKE OKEECHOBEE WATERWAY

Source: U.S. Army Corps of Engineers. Lake Okeechobee Waterway Recreation Map.

would have a combined lift of approximately 15.5 feet and 14.5 feet, respectively. The difference is explained by the Caloosahatchee locks releasing further inland (upstream) from the coast than the St. Lucie locks. Three of the locks have head differences of several feet. However, two locks have significantly larger head differences. Ortona Lock has a head difference of approximately 8 feet, and St. Lucie typically has lift elevations in excess of 13 feet. The chamber depths of the five locks depend on the lock head. At their lowest operational levels, the chambers would have depths far in excess of the authorized project depths. Therefore, the lock chambers do not constitute depth constraints to waterway traffic under conceivable circumstances.

**TABLE 4-3**
**LOCK DIMENSIONS**
**LAKE OKEECHOBEE WATERWAY**

| Lock | Dimensions (feet) |
|---|---|
| St. Lucie | 50' x 250' |
| Port Mayaca | 56' x 400' |
| Moore Haven | 50' x 250' |
| Ortona | 50' x 250' |
| W.P. Franklin | 56' x 400' |

## 4.2 WATERWAY OPERATION

As previously discussed, the Caloosahatchee River and the St. Lucie Canal are primary outlets for Lake Okeechobee. They are also critical components of the Lake Okeechobee Waterway. The locks and dams are operated in a manner that supports commercial navigation as well as other project objectives. Each of the locks and dams has a spillway that can be used for the lake's regulatory releases. The spillways and the locks release freshwater downstream and eventually into the Gulf of Mexico and the Atlantic Ocean. Releases are carefully controlled to regulate lake levels, maintain adequate depths for navigation in the two outlet waterways, and minimize salinity impacts on the two receiving estuaries.

Water is typically released through the Caloosahatchee River before the St. Lucie Canal for two reasons. First, freshwater releases to the St. Lucie Canal are limited due to greater ecological effects of freshwater releases on the estuary. Second, the water treatment facility for the town of Olga is located in the Caloosahatchee reach between the W.P. Franklin and Ortona locks. The plant is not allowed to discharge chloride-treated effluent to the river if chloride concentrations in the receiving waters are in excess of 250 parts per million (ppm). The three Caloosahatchee locks and dams are typically operated to keep salinity in this river reach low enough to receive the plant effluent. Since the Caloosahatchee River downstream of W.P. Franklin is tidal, this involves a continual release of freshwater from the lake. In addition, the lock operators will occasionally flush the waterway to remove algae and to restore dissolved oxygen levels. In the St. Lucie Canal, the St. Lucie Lock is the main interface between the lake and the Atlantic Ocean. When the lake level is below 14 feet NGVD, the Port Mayaca Lock is opened, and water levels for the reach from the lake to the St. Lucie lock are controlled by lake levels.

During water shortages, the operation of the Lake Okeechobee Waterway is altered. In all four phases of the SFWMD's Water Shortage Plan, lock operations can be restricted to conserve water in Lake Okeechobee and maintain acceptable salinity concentrations in the estuaries downstream of the locks. The operation of the W.P. Franklin Lock is a particular focus of the plan. Under the Plan, the SFWMD will request the Corps to limit lockages at W.P. Franklin to once every 4 hours if chloride concentrations at the lock exceed 180 ppm and a rainfall event in excess of 1 inch in 24 hours is not predicted in the surface water use basin within the next 48 hours. If these restrictions are insufficient to reach the salinity target at W.P. Franklin, the SFWMD can then request the Corps to restrict lockages to once every 4 hours, twice per week. If these additional measures are insufficient, the SFWMD can ask the Corps to prohibit lockages.

## 4.3 WATERWAY USE

As shown in Table 4-4, the Lake Okeechobee Waterway was used to transport 430,000 tons of freight in 1995. This table, which contains statistics from Waterborne Commerce of the United States, indicates that petroleum products comprise the overwhelming majority of tonnage shipped. Petroleum products included distillate fuel oil, residual fuel oil, and liquid natural gas (see detailed tabulation of freight traffic contained in Appendix A). As indicated in Table 4-5, commercial navigation on this waterway has been relatively stable over the past ten years with substantial variability year to year.

**TABLE 4-4**
**FREIGHT TRAFFIC, 1995**
**Lake Okeechobee Waterway**
**(thousand tons)**

| Commodity | Total | Coastwise – Through | | ← Internal → | | |
|---|---|---|---|---|---|---|
| | | Upbound (east to west) | Downbound (west to east) | Inbound Upbound | Through Downbound | Intra-Upbound |
| All Commodities | 430 | 8 | 1 | 415 | 6 | 1 |
| Total Petroleum Products | 423 | 7 | 0 | 411 | 5 | 0 |
| Total Primary Manufactured | | | | | | |
| Total Food & Farm Products | 3 | | | 2 | | 1 |
| Total Manufactured Equipment & Machinery | 3 | 1 | 1 | | 1 | |
| Ton-Miles (000's) | 9,758 | 1,187 | 179 | 8,265 | 125 | 1 |

Source: U.S. Army Corps of Engineers, Waterborne Commerce of the United States, 1996.

**TABLE 4-5**
**FREIGHT TRAFFIC, 1986-1995**
**Lake Okeechobee Waterway**
**(thousand tons)**

| Year | Total Tons |
|---|---|
| 1986 | 1320 |
| 1987 | 676 |
| 1988 | 696 |
| 1989 | 680 |
| 1990 | 665 |
| 1991 | 718 |
| 1992 | 753 |
| 1993 | 832 |
| 1994 | 662 |
| 1995 | 430 |

Source: U.S. Army Corps of Engineers, Waterborne Commerce of the United States, 1996.

The locks on the Lake Okeechobee Waterway play critical roles in movements of commercial vessels on these waterways. Also, the lock operators maintain records of the lock operations, including the general characteristics of vessels passing through the locks. These data are compiled in a national database, the Lock Performance Monitoring System (LPMS). This database is maintained by the Navigation Data Center at the Corps of Engineers Water Resources Support Center in Washington. D.C.

Data from the LPMS includes characteristics of the commerce vessels used on the waterway. Table 4-6 summarizes the LPMS vessel profiles for the Lake Okeechobee Waterway locks for 1996. The full LPMS descriptions of the lock performances for 1991-1996 are contained in Appendix B. The lock data contains information about recreational boats passing through the locks, as well as commercial traffic.

The number of tows passing through the locks range from 97 to 226 for W.P. Franklin and the St. Lucie locks, respectively. The average number of barges per tow is small, ranging from 1.1 to 1.5 for St. Lucie and Port Mayaca locks, respectively. The relatively light volume of traffic and the small tow sizes explain the minimal delays at the waterway locks, as found in Appendix B.

Additional data on the commercial vessels using the Lake Okeechobee Waterway is provided in Table 4-7, which presents Florida state vessel registrations for the counties surrounding the lake. This table includes commercial and recreational vessels by length class. The vessels in this table are primarily small, recreational craft. However, there are larger commercial vessels as well. There is a small but viable fleet of day/dinner cruise vessels that operate during the tourist season from Pahokee, on the eastern shore of the lake, and from Ft. Myers. These vessels have relatively shallow drafts, in the range of four to five feet. The smaller commercial craft may be

**TABLE 4-6**
**VESSEL PROFILES**
**LAKE OKEECHOBEE WATERWAY LOCKS**
**January – December 1996**

| | Vessels | | | | Barges | | | Bottoms Total | Tons (000) |
|---|---|---|---|---|---|---|---|---|---|
| | Total | Recreation | Tows | Other | Total | Loaded | Empty | | |
| **St. Lucie** | | | | | | | | | |
| Upbound | 4500 | 3859 | 116 | 525 | 134 | 82 | 52 | 4634 | 8 |
| Downbound | 4444 | 3759 | 110 | 575 | 122 | 95 | 27 | 4566 | 15 |
| Total | 8944 | 7618 | 226 | 1100 | 256 | 177 | 79 | 9200 | 23 |
| **Port Mayaca** | | | | | | | | | |
| Upbound | 4420 | 3448 | 54 | 918 | 67 | 34 | 33 | 4487 | 5 |
| Downbound | 4348 | 3349 | 49 | 950 | 89 | 69 | 20 | 4437 | 8 |
| Total | 8768 | 6797 | 103 | 1868 | 156 | 103 | 53 | 8924 | 13 |
| **Moore Haven** | | | | | | | | | |
| Upbound | 5287 | 5054 | 70 | 163 | 84 | 65 | 19 | 5371 | 9 |
| Downbound | 5441 | 5220 | 73 | 148 | 84 | 48 | 36 | 5525 | 7 |
| Total | 10728 | 10274 | 143 | 311 | 168 | 113 | 55 | 10896 | 16 |
| **Ortona** | | | | | | | | | |
| Upbound | 3925 | 3744 | 54 | 127 | 70 | 57 | 13 | 3995 | 9 |
| Downbound | 4090 | 3921 | 54 | 115 | 70 | 37 | 33 | 4160 | 4 |
| Total | 8015 | 7665 | 108 | 242 | 140 | 94 | 46 | 8155 | 13 |
| **W.P. Franklin** | | | | | | | | | |
| Upbound | 8115 | 7872 | 46 | 197 | 66 | 47 | 19 | 8181 | 8 |
| Downbound | 8362 | 8141 | 51 | 170 | 75 | 36 | 39 | 8437 | 5 |
| Total | 16477 | 16013 | 97 | 367 | 141 | 83 | 58 | 16618 | 13 |

Source: U.S. Army Corps of Engineers, Lock Performance Monitoring System, 1997.

fishing boats associated with marinas or fish camps on the lake. These operations will rent fishing boats, and they offer guide services as well. The vessel registration information in Table 4-7 must be interpreted with caution for two reasons. First, Palm Beach and Martin Counties are coastal counties with potential vessel registrations for the Lake Okeechobee Waterway and the Atlantic Ocean. Second, the county of registration may not necessarily be the same as the county of operation.

## 4.4 EVALUATION OF ALTERNATIVE REGULATION SCHEDULES

The economic effects on commercial navigation are the changes in the value of resources required to transport commodities and the increase in the value of output from these goods and services. Changes in transportation costs may stem from changes in: (1) the vessel fleet used on the waterways, (2) efficiency in the use of existing vessels, (3) transit time, (4) origin-destination patterns, (5) cargo handling, (6) tug assistance, and (7) use of waterborne transportation, rather than competing modes. The NED effects include the costs of resources, impacts on net income, and operating costs.

**TABLE 4-7**
**VESSEL REGISTRATIONS**
**LAKE OKEECHOBEE COUNTIES**
**FY 1996-1997**

| Class | Length | Type | Glades | Hendry | Martin | Okeechobee | Palm Beach | Total |
|---|---|---|---|---|---|---|---|---|
| Class A-1 | <12' | Pleasure | 72 | 349 | 1,785 | 297 | 6,415 | 8,918 |
| | | Commercial | 12 | 13 | 70 | 11 | 108 | 214 |
| Class A-2 | 12'-15'11' | Pleasure | 371 | 832 | 2,270 | 1,603 | 6,405 | 11,481 |
| | | Commercial | 70 | 58 | 71 | 115 | 88 | 402 |
| Class 1 | 16'-25'11' | Pleasure | 577 | 1,328 | 7,141 | 2,624 | 15,372 | 27,042 |
| | | Commercial | 65 | 115 | 262 | 141 | 430 | 1,013 |
| Class 2 | 26'-39'11" | Pleasure | 30 | 213 | 1,876 | 73 | 3,187 | 5,379 |
| | | Commercial | 4 | 33 | 132 | 1 | 196 | 366 |
| Class 3 | 40'-64'11" | Pleasure | 7 | 49 | 343 | 8 | 735 | 1,142 |
| | | Commercial | 2 | 9 | 79 | 3 | 109 | 202 |
| Class 4 | 65'-109'11" | Pleasure | 0 | 1 | 14 | 0 | 58 | 73 |
| | | Commercial | 0 | 1 | 3 | 0 | 19 | 23 |
| Class 5 | >110' | Pleasure | 0 | 0 | 0 | 0 | 6 | 6 |
| | | Commercial | 0 | 0 | 0 | 0 | 0 | 0 |
| Canoes | | Pleasure | 14 | 22 | 126 | 15 | 241 | 418 |
| | | Commercial | 0 | 2 | 1 | 0 | 0 | 3 |
| | Sub-total | Pleasure | 1,071 | 2,794 | 13,555 | 4,620 | 32,419 | 54,459 |
| | Sub-total | Commercial | 153 | 231 | 618 | 271 | 950 | 2,223 |
| | | **TOTAL** | 1229 | 3039 | 14,458 | 4,911 | 33,639 | 57,276 |

Source: Bureau of Vessel Titles and Registrations, Florida Department of Highway Safety and Motor Vehicle. 1997.

The statistics on waterborne commerce and vessels on the Lake Okeechobee Waterway were complemented by extensive field research. This research included interviews with: (1) lockmasters of each lock, (2) waterway users, (3) waterway interest groups, and (4) Corps operations personnel involved with the Lake Okeechobee Waterway project. These interviews solicited opinions regarding the potential navigation impacts from changes in the lake's regulation schedule. In addition, the waterway was traversed as part of this field research to identify the sensitivity of commercial navigation to changes in lake levels. This included taking spot soundings to assess channel conditions and evaluating aids to navigation. The findings of this field research are highlighted below.

### 4.4.1 Commercial Traffic

Based on conversations with representatives of the Florida Inland Navigation District, the current and former presidents of the Lake Okeechobee Waterway Association, and the lockmasters, there are no commercial shipping lines which regularly pass through the Lake Okeechobee waterway.

As a result, there is no fleet of regular commercial waterway users, and there is no regular routing of commodity shipments through the waterway. The commercial traffic consists of special barge shipments that are taking advantage of the shortcut across the peninsula, which can save 3 to 5 days of travel. In some cases, deep-draft tugs transfer the tows to shallow-draft tugs for passage through the Lake Okeechobee Waterway.

In the absence of an established fleet of vessels using the waterway, the analysis of commercial navigation must depend on records of the ad hoc shipments collected as part of the waterborne commerce statistics and the LPMS. It was beyond the scope of this investigation to collect primary data by identifying and interviewing shippers who may use this waterway regarding waterway navigation and their decision making regarding vessels and origin-destination patterns.

The absence of regular vessel traffic through the Lake Okeechobee Waterway combined with the historic profiles of commodities and vessels suggest that commercial navigation on this waterway will continue at its current level with the same high year-to-year variability experienced in the last decade. It is not possible to estimate how the fleet of commercial vessels using the waterway might change with the modification of the lake regulation schedule. However, very little change, if any, would be expected, since the differences between the stage-duration curves of the alternatives are small and there is no dedicated fleet.

### 4.4.2 Groundings

Interviews held with the lockmasters and Corps operations personnel suggested that when lake levels are below 14 feet NGVD, the frequency of vessel groundings increases. While the problem is most severe for recreational vessels, commercial traffic is subject to groundings, as well. In general, groundings occur when vessels do not stay in the channel. Since most commercial vessels will endeavor to remain in the channel, groundings are less of a problem for them than recreational craft. However, at very low lake levels, the authorized channel depths cannot be maintained. Under these circumstances, the Coast Guard will install temporary markers to keep vessels in deep water within the channels. The Coast Guard will also issue a Notice to Mariners warning commercial and recreational navigators about the reduced channel depths.

Of particular concern are two shoal areas that pose hazards to vessels that have drafts close to the authorized channel depth. During average and high lake levels these shoals are not a threat to commercial navigation, but during low lake stages they can be problematic. In particular, there is a rock shelf on Route 2 near Port Mayaca lock and Rocky Reef on Route 1 near Clewiston that are hazardous. At Port Mayaca, the shoal allegedly has only 4.5 feet of water at lake level 12.56 feet NGVD; and the Clewiston entrance allegedly has less than 8 feet of water at the same lake level.

As lake levels decline, there is less margin for error. If commercial vessels stray outside of the channel for any reason, they can run aground. Rocky Reef on Route 1 near Clewiston is particularly unforgiving of errors. Much of the lake bottom is soft, but running aground at this location could cause severe damage to vessels. For commercial traffic, it can be particularly challenging to stay in the smaller channel during low lake levels due to the wave and wind action for which Lake Okeechobee is famous. The lower lake levels compound problems with waves, since the shallower depths exacerbate wave formation.

If vessels run aground, the Coast Guard at Ft. Pierce is contacted, and a tow from Ft. Meyers is requested. If there is danger to life or property, the Corps project operations office in Clewiston, on the southwestern edge of the lake, will provide assistance. The Corps keeps records of such assistance, but only for two years. As a result, information about groundings on the lake is primarily anecdotal.

### 4.4.3 Aids To Navigation

Based upon a detailed inspection of the Lake Okeechobee Waterway, it appears there are some problems with aids to navigation that pose hazards to commercial and recreation vessels. Route 1 across the lake is particularly problematic in this regard. Specifically, the channel markers appear to be spaced too far apart for safe navigation. In particular, offshore from Clewiston, Route 1 turns sharply northward to pass through Rocky Reef at the "Hole in the Wall." There are three buoys that mark the channel through this turn: one for the approach, one for the pivot point, and one for exit. The problem is that inexperienced mariners might be tempted to cut across the hypotenuse of what is almost a right triangle, moving directly from the approach to the exit buoy. Unfortunately, this would be a path directly over the reef. This path might not be problematic during average or high lake levels, but at low lake levels groundings would result.

In addition, waterway users indicate that in many locations the waterway buoys exceed the channel dimensions significantly. Again, during average or high water, this may not be a problem, but during low lake levels, shallow water could be encountered, as evidenced by the Coast Guard's placement of temporary markers.

Finally, on Route 1, the channel marker buoys seem to be spaced too far apart. While compass headings for this route are provided in navigational charts for the lake, visual cues (i.e., confirmation) using the channel markers are not possible at some points along this route, particularly offshore of Port Mayaca.

### 4.4.4 Lockage Restrictions During Water Shortages

Restrictions on lockages during water shortages causes delays to commercial and recreational waterway traffic. Delays are offset to some degree by the opening of the Port Mayaca lock during low lake levels. However, there are economic effects associated with these delays, particularly for commercial traffic. Although the restriction of lockages as a result of water shortages is uncommon, the restrictions are perceived by the lockmasters as unnecessarily rigid. The lockmasters report that lockages have been restricted at the same time as water releases over the dam spillways were being conducted to control salinity in the waterways and the estuaries. During normal operations, the locks are operated on demand. The lockmasters acknowledge that lockages should be restricted during water shortages, but they suggest that they be given more flexibility to manage lock operations with open-ended performance measures, such as requirements not-to-exceed a specified number of lockages over a given time period.

### 4.4.5 Extreme Scenario of Navigation Impacts

To place the potential economic effects of the alternative regulation schedules in perspective, an extreme scenario that maximizes the potential impacts of lake regulation on commercial navigation can be constructed for the 2010 (future) condition using available information. This scenario assumes the following:

- When lake stages fall below 11 feet NGVD, all commercial traffic through the waterway is re-routed around the Florida peninsula due to low waterway depths and/or lockage restrictions.
- Travel time around the peninsula requires four days.
- Travel time using the waterway is 20.5 hours (154 mile waterway; average speed: 6.5 miles/hour; lock delays per 1996 LPMS data).
- Events with lake levels less than 11 feet NGVD for more than 100 days (per Figure 4-1) last 4 months.
- There are 97 tows per year (8 per month), per W.P. Franklin 1996 LPMS data.
- A shallow-draft tug (1000 hp) would move the tows in the waterway, and a seagoing tug would move them around the peninsula.
- The representative barge is 1500 tons, and the representative tow size is 1.5 barges.

Using the above assumptions, the additional costs incurred for a shipper to detour around the peninsula rather than use the waterway would be $22,391 per trip. This represents the difference between $2,181.07 to use the waterway (i.e., 24.1 hours * $90.64 per hour) and $24,572 to go around the peninsula (i.e., 4 days * $6,143 per day). Operating costs were derived from the Corps of Engineers Institute for Water Resources Draft FY 97 Shallow Draft Operating Costs and Draft FY 97 Deep Draft Operating Costs .

Using this estimate of detour costs and the SFWMM output defining the instances in which lake levels would be under 11 feet NGVD yields the following average annual changes in transportation costs associated with the alternative regulation schedules, relative to the existing regulation schedule: Run22AZE: -$46,226 (additional costs), WSE: -$23,113(additional costs), COEREC: no change, HSMREC: +$23,113 (cost savings).

## 4.5 ASSESSMENT

Based upon field research and database searches regarding commercial navigation on the Lake Okeechobee Waterway, it can be concluded that the effects of the alternative regulation schedules on the NED account would be very small, as evidenced by the "worst case" scenario described above. There are some commercial navigation issues on this waterway, all of which are directly or indirectly related to lake levels. However, it is not possible to quantify the impacts of the alternative regulation schedules without extensive research to identify the waterway fleet and commodity flows. In addition, the infrequent and irregular nature of navigation on the waterway raises the question of whether shipments through the waterway could be deferred until lake levels increase, with little ill effect. In addition, those shippers who use this waterway may already have adjusted to the fluctuations in lake levels. Revisions in lock management practices during drought conditions, as suggested by the lock masters, could also reduce the impacts of the alternative regulation schedules on commercial traffic. Finally, the combination of the minor difference in the frequency of extreme low lake levels between the alternative schedules and relatively light commercial traffic on the waterway supports the conclusion that the impacts of the alternative regulation schedules on commercial navigation will be negligible.

# 5. RECREATION

## OVERVIEW

The alternative regulation schedules could have implications for outdoor recreation throughout south Florida. The schedules could change the hydrologic regimes of Lake Okeechobee and other waterways that constitute the regional water management system of south Florida. These changes could affect water-based recreation throughout the region.

In this chapter, the potential economic effects of the alternative regulation schedules on recreation are examined. The discussions focus on water-based recreation, specifically recreational navigation (i.e., boating) and sportfishing. Commercial (i.e., guided) sportfishing is also included in these discussions.

The alternative regulation schedules have the potential to contribute to the restoration of the Everglades ecosystems. They could therefore provide recreational benefits for ecotourism-related activities throughout the region. However, based on available data and modeling capabilities, no quantitative, causal linkage can currently be established between lake regulation, ecosystem response, and ecotourism levels in the Everglades. Consequently, the assessment of recreation impacts of the LORSS alternatives will be limited to recreational activities that occur on Lake Okeechobee and its immediately adjacent waterways and associated landside facilities.

The economic effects of the alternative regulation schedules on recreation are estimated by quantifying the differences in the quantity and quality of recreation activities expected to occur under with- and without-project conditions. Estimating the change in economic value of recreational activities can be approached in three steps: (1) identifying the recreational resources of the lake and its associated waterways, (2) evaluating the quality and quantity of recreation activities under the with- and without-project conditions, and (3) comparing these quantities and qualities to estimate the effects of the alternative regulation schedules.

## 5.1 RECREATION RESOURCES

Lake Okeechobee is the largest recreational resource in the region. The lake and its associated waterways and shoreline provide a wide variety of water-based recreation activities for local residents and out-of-state visitors, including: fishing, boating, picnicking, sightseeing, camping, swimming, hunting, air boating, and hiking. The western side of the lake is relatively shallow, with an extensive littoral zone, which comprises approximately one-quarter of the lake area. The littoral zone provides critical habitat for the lake's popular sport fishery and attracts thousands of waterfowl, which lure hunters during the fall migration.

Lake Okeechobee is recognized as supporting one of the best recreational fisheries in the nation. The recreational fishery includes individual anglers fishing from boats and the shore, as well as guided sportfishing. The fishery is large and productive due to the extensive littoral zone which provides abundant habitat for juvenile and adult fish. A creel (i.e., fish catch) survey of lake fishermen conducted by the Florida Game and Fresh Water Fish Commission during the 1990-

1991 season indicated that largemouth bass and black crappie fisheries are thriving. During the survey period, there was a record high of 151,915 largemouth bass caught with a record low angling effort of 264,764 hours. The resulting success rate was 0.58 bass per hour. The black crappie fishery also exhibited record levels during the survey period with 2,084,749 fish taken over 735,795 hours, with a record angler success rate of 2.79 fish per hour.

Field discussions with lake anglers suggest that in recent years, the black bass fishing has declined somewhat, and many bass fishermen have started to fish for crappie. Nonetheless, by all accounts, the sport fishery on the lake remains healthy at this time. Black crappie are fished most heavily on the north end of the lake and are fished year round by local residents. The season peaks from December to May with an influx of black crappie anglers. Peak bass season begins in December and lasts through March. Bass are fished with even pressure from the north, west and south regions of the lake. Bream (bluegill and redear sunfish) season peaks from March through July. Bream are fished primarily on the western side of the lake.

As part of the field research conducted for this investigation, most of the recreational facilities on Lake Okeechobee, the Caloosahatchee River, and the St. Lucie Canal were visited. This included Corps recreation sites, recreation facilities of other agencies, boat ramps, marinas, fish camps, levee trails, and campgrounds. The site visits had three principal goals: (1) to assess the features of the recreation facilities, (2) to evaluate recreational activities and usage levels, and (3) to determine the sensitivity of recreational facilities and activities to changes in lake levels. Profiles of the main recreation sites on the Lake Okeechobee Waterway are presented in Table 5-1. As indicated in this figure, there are 39 recreational sites on the waterway. The number designated sites in this figure correspond to those illustrated in Figure 4-2.

As indicated in Table 5-1, there are 34 boat launching sites which provide access to the lake. The ramps were of particular interest in this investigation, since ramp access to the lake could be affected by fluctuations in lake levels that result from the implementation of the alternative regulation schedules. Only those facilities on the lake that could be affected by changes in lake levels were evaluated. For example, the ramps and marinas along the Caloosahatchee River were not examined in detail. The water levels in this waterway would not fluctuate with changing lake levels, since stages in the river are controlled by the three Caloosahatchee locks. Under most circumstances, the St. Lucie Canal would also not be affected by changing lake levels. However, when the lake levels fall below 14 feet NGVD, the Port Mayaca Lock is opened and the canal fluctuates with lake levels. For this reason, the recreation facilities on this waterway were examined in detail.

In addition to the boat launch ramps, the marinas on the Lake Okeechobee Waterway were visited and evaluated for their sensitivity to lake level fluctuations. There are seven commercial marinas on the waterway, providing a variety of services to boaters. In addition, there are approximately one dozen fish camps along the lake that rent fishing boats, offer guide services, and provide lodging.

At each of the marinas and boat launching ramps, spot soundings were taken at the entrance channels and end of ramps to determine whether use of and access to these facilities could be affected by changes in lake levels. In addition, marina dockmasters were interviewed to determine the depths of their access channels and boat slips.

## TABLE 5-1
## RECREATIONAL FACILITIES, LAKE OKEECHOBEE WATERWAY

| | Corps Operated | Campsites | Showers | Drinking Water | Sanitary | Day Use | Launch Ramp | Marina | Boat-In Camping | Fishing Pier |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. W.P. Franklin Lock and Dam (North) | • | • | • | • | • | | • | | • | • |
| 2. W.P. Franklin Lock and Dam (South) | • | | • | • | | • | • | | | |
| 3. Alva Access Area | • | | | | | | • | | | |
| 4. La Belle Lions Park | | | | | | • | | | | |
| 5. La Belle Access Area | | | | | | • | • | | | |
| 6. Barron Park | | | | • | | • | | | | |
| 7. Belle Hatchee Marina | | | • | • | | | • | • | | |
| 8. Port La Belle Marina | | | • | • | | | • | • | | |
| 9. Ortona Lock and Dam (North) | • | | | • | | • | • | | | • |
| 10. Ortona Lock and Dam (South) | • | • | • | • | • | • | | | | • |
| 11. Moore Haven Lock (East) | • | | | | | | | | | • |
| 12. Moore Haven Recreational Village | | • | • | • | • | • | • | • | | |
| 13. Sportsman's Village | | | | | | • | • | | | |
| 14. Fisheating Creek | | | | | | | • | | | |
| 15. Harney Pond Canal | | | | • | | • | • | | | • |
| 16. Bare Beach | | | | | | • | • | | | |
| 17. Indian Prarie Canal | | | | | | | • | | | • |
| 18. Okee-Tanti | | • | • | • | • | • | • | • | | |
| 19. C.Scott Driver | | | | | | | • | | | |
| 20. Okeechobee | | | | • | | • | • | | | • |
| 21. Taylor Creek | | | | | | | • | | | |
| 22. Nubbin Slough | | | | | | | • | | | |
| 23. Henry Creek | | | | | | | • | | | |
| 24. Chancy Bay | | | | | | | • | | | |
| 25. Port Mayaca Lock and Dam | • | | | | | • | • | | | |
| 26. Canal Point | | | | | | • | • | | | |
| 27. Pahokee | | • | • | • | • | • | • | • | | • |
| 28. Paul Rardin Park | | | | • | | • | • | | | |
| 29. Belle Glade | | • | • | • | • | • | • | • | | • |
| 30. South Bay | | | | | | • | • | | | |
| 31. John Stretch Park | | | | • | • | • | • | | | |
| 32. Corps South Florida Operations | • | | | | | | • | | | |
| 33. Clewiston Park | | | | | | • | • | | | • |
| 34. Liberty Point | | • | • | • | | | • | | | |
| 35. Alvin Ward | | | | • | | • | • | | | |
| 36. Port Mayaca Wayside Park | | | | | | • | | | | |
| 37. Indiantown Marina | | • | • | • | | • | • | • | | • |
| 38. St. Lucie Lock and Dam | • | • | • | • | • | • | • | | • | • |
| 39. Phipps Martin County Park | | • | • | • | • | • | • | | | |

Source: U.S. Army Corps of Engineers. Lake Okeechobee Waterway Recreation Map.

## 5.2 Recreation Activity

In addition to field research, a variety of secondary information sources about recreation on the Lake Okeechobee Waterway were consulted during this study. Some of these documents described recreation facilities on the lake. These included Corps documents such as the Lake Okeechobee Waterway Project Management Plan and the Lake Okeechobee Waterway Shoreline Master Plan. Other documents focused on recreation activities. These included the Florida Statewide Comprehensive Outdoor Recreation Plan (SCORP), The Economic Impact and Valuation of the Recreational and Commercial Fishing Industries on Lake Okeechobee, Florida (Bell, 1987), and a variety of articles on the lake's fishery prepared by the Florida Game and Freshwater Fish Commission. Also, a series of telephone interviews was conducted with experts on Florida's tourism industry, including: (1) representatives of the Division of Recreation and Parks of the Florida Department of Environmental Protection and (2) academic recreation and tourism specialists at the University of Florida Center for Tourism Research and Development and at Florida State University.

## 5.3 RECREATION RESOURCE USAGE

The best estimates of current usage of the lake's recreation resources are contained in the Natural Resource Management System (NRMS), a database that contains usage data for all Corps recreation projects. Table 5-2 presents the NRMS data for FY 1992 to FY 1996. This table contains monthly visitor hours, total visitors, and estimates of recreation activities during visitation. While the visitor hours have varied somewhat over time, the number of visitors to Lake Okeechobee has risen steadily. Sightseeing, fishing, and boating are among the most popular recreational activities on this waterway.

## 5.4 FUTURE RECREATION DEMAND

The best estimate of future recreation demand is found in the Statewide Comprehensive Outdoor Recreation Plan (SCORP). The SCORP divides Florida into recreation regions, including south Florida. The SCORP categories that apply to recreation on the Lake Okeechobee Waterway are: freshwater fishing (boat), freshwater fishing (non-boat), nature study, freshwater boat ramp use, and canoeing. The 1995 and 2000 estimates for recreation demand (in user occasions) for these categories are presented in Table 5-3. The popularity and growth of nature study as a recreational activity is evident in this table.

## 5.5 FIELD SURVEY

As part of the field research conducted for this study, a license plate survey was conducted for all boat launching sites on Lake Okeechobee and the St. Lucie Canal on Saturday, 22 November and Sunday, 23 November 1997. This survey consisted of a visit to the 20 launch sites to assess usage levels at the ramps during this weekend. November 22 was the opening of duck hunting season. Consequently, the boat ramps on the west side of the lake were extremely active. As indicated in Figure 4-2, this side of the lake is shallow and contains abundant littoral habitat which attracts waterfowl.

# TABLE 5-2
# NRMS DATA
# LAKE OKEECHOBEE WATERWAY
# FY 1992 – FY1997

| | | FY 96 | FY 95 | FY 94 | FY 93 | FY 92 |
|---|---|---|---|---|---|---|
| 1. Visitor Hours | October | 9,640,500 | 6,310,300 | 1,073,200 | 1,022,500 | 1,011,300 |
| | November | 6,763,700 | 7,084,200 | 1,075,800 | 1,024,500 | 979,800 |
| | December | 8,456,200 | 9,609,500 | 5,633,700 | 5,365,500 | 5,047,700 |
| | January | 8,245,500 | 11,697,100 | 7,245,700 | 5,656,400 | 5,299,900 |
| | February | 8,314,500 | 12,130,300 | 6,048,800 | 6,185,800 | 5,548,100 |
| | March | 10,871,000 | 11,464,900 | 2,493,600 | 2,,416,500 | 2,162,500 |
| | April | 2,240,800 | 2,961,400 | 2,448,300 | 2,408,500 | 2,700,900 |
| | May | 1,862,900 | 1,953,100 | 3,089,600 | 2,491,500 | 2,352,800 |
| | June | 2,125,400 | 2,529,600 | 1,148,000 | 2,317,400 | 2,250,500 |
| | July | 2,078,400 | 2,029,100 | 1,632,500 | 2,257,700 | 2,147,000 |
| | August | 2,137,000 | 2,078,800 | 1,386,500 | 2,440,000 | 2,325,000 |
| | September | 1,767,600 | 1,622,300 | 925,600 | 1,037,500 | 1,022,100 |
| | Total | 64,503,500 | 71,470,600 | 34,201,300 | 34,623,800 | 32,847,600 |
| 2. Dispersed Use Visitor Hrs. | | 1,290,100 | 1,429,400 | 5,130,200 | 525,000 | 513,001 |
| 3. Total Number of Visitors | | 6,695,300 | 6,589,700 | 5,507,600 | 5,693,400 | 5,130,018 |
| 4. Picnicking % | | 12 | 13 | 12 | 12 | 12 |
| 5. Camping % | | 5 | 5 | 3 | 3 | 3 |
| 6. Swimming % | | 2 | 2 | 8 | 8 | 8 |
| 7. Water Skiing % | | 1 | 1 | 1 | 1 | 1 |
| 8. Boating % | | 23 | 23 | 19 | 19 | 20 |
| 9. Sightseeing % | | 45 | 45 | 49 | 49 | 47 |
| 10. Fishing % | | 27 | 27 | 24 | 24 | 23 |
| 11. Hunting % | | 1 | 1 | 2 | 0 | 0 |
| 12. Winter Recreation % Use | | 0 | 0 | 0 | 0 | 0 |
| 13. Others % | | 9 | 8 | 9 | 9 | 9 |

Source: U.S. Army Corps of Engineers. Natural Resources Management System.

The results of this survey are contained in Appendix C. Only vehicles with boat trailers were included in this survey. This spot survey identified 569 boat trailers parked at boat launch sites. At these sites there were a combined total of approximately 945 parking spaces which were empty, indicating substantial surplus recreational capacity even on the first day of waterfowl hunting season. The origins of the trailers were determined from the license plates, since Florida plates typically display the county of vehicle registration. As evident in Appendix C, there were 33 Florida counties represented at the launch sites, as well as 12 other states. The counties with the highest representation were those counties adjacent to the lake.

**TABLE 5-3**
**ESTIMATED RECREATION DEMANDS (IN USER OCCASIONS)**
**1995, 2000**

| | 1995 | 2000 | % Change (1995-2000) |
|---|---|---|---|
| Fishing (boat) | 302,805 | 333,098 | 10% |
| Fishing (non-boat) | 705,122 | 753,252 | 7% |
| Nature Study | 1,129,877 | 1,296,006 | 15% |
| Boat Ramp | 134,471 | 152,455 | 13% |
| Canoeing | 267,223 | 304,650 | 14% |

Source: Florida Statewide Comprehensive Outdoor Recreation Plan. 1997.

## 5.6 ESTIMATED VALUE OF RECREATION RESOURCES

The information presented previously on the type, quality, and quantity of recreation resources at Lake Okeechobee can be used to estimate the value of the recreational resource. As specified in Corps guidance (ER 1105-2-100), the value of a project's recreation resources should be measured in terms of willingness to pay. The following methodologies can be used to estimate willingness to pay: the travel cost method (TCM), the contingent valuation method (CVM), and the unit day value (UDV) method. Either the CVM or TCM approaches are typically required for projects, like Lake Okeechobee, that exceed 750,000 visitor days per year. However, the LORSS project is a ecosystem restoration effort. The analysis of economic effects is being conducted to provide information to support project decision making, but a benefit cost analysis is not required. Therefore, the UDV method was selected as the means to estimate the value of recreation resources at Lake Okeechobee, since the more extensive analyses required by the travel cost and the contingent valuation methods are not needed to support project justification. The UDV method relies on informed opinion and judgment to estimate the average willingness to pay for recreation experiences of various types and quality levels.

The UDV evaluation procedure requires that the analyst select a specific point estimate from within a range agreed upon by Federal water resource agencies to reflect the quality of the recreational experience along the following dimensions:

- Quality and availability of multiple recreation experiences
- Relative scarcity of the specific recreational experience within the region
- Adequate carrying capacity, without deterioration of the resource or experience
- Easy access to the recreation site(s)
- Aesthetic quality of the environment.

The points assigned to each dimension are then summed to yield a total quality estimate for the project site under both with- and without-project conditions (maximum score = 100). The total quality points are then correlated to a specific dollar value which is intended to approximate an individual's willingness to pay for a day of recreation experience. The conversion factor from points to dollar value is specified in a Economic Guidance Memorandum published annually by the Corps of Engineers. The individual valuation of the recreation experience is then multiplied by demand to estimate total recreation value. Value ranges and factors used in evaluating recreation characteristics (provided in ER 1105-2-100) are shown in Table 5-4.

Points for each of the five categories were assigned to general recreation and hunting/fishing based on the documents, data, and field work described above. These point assignments were made in consultation with Corps Jacksonville District personnel who participated in the field visitation of Lake Okeechobee recreation facilities. The point assignments are presented in Table 5-5.

## TABLE 5-4
## GUIDELINES FOR ASSIGNING POINTS FOR RECREATION FACILITIES

| Criteria | Judgement Factors | | | | |
|---|---|---|---|---|---|
| Recreation experience | Two general activities | Several general activities | Several general activities; one high quality value activity | Several general activities; more than one high quality value activity | Number of high quality value activities; some general activities |
| Total Points: 30<br>Point Value: | 0-4 | 5-10 | 11-16 | 17-23 | 24-30 |
| Availability of opportunity | Several within 1 hour travel time; a few within 30 minutes travel time | Several within 1 hour travel time; none within 30 minutes travel time | One or two within 1 hour travel time; none within 45 minutes travel time | None within 1 hour travel time | None within 2 hours travel time |
| Total Points: 18<br>Point Value: | 0-3 | 4-6 | 7-10 | 11-14 | 15-18 |
| Carrying capacity | Minimum facility for development of public health and safety | Basic facility to conduct activities | Adequate facilities to conduct without deterioration of the resource or activity experience | Optimum facilities to conduct activity at site potential | Ultimate facilities to achieve intent of selected alternative |
| Total Points: 14<br>Point Value: | 0-2 | 3-5 | 6-8 | 9-11 | 12-14 |
| Accessibility | Limited access by any means to site or within site | Fair access, poor quality roads to site; limited access within site | Fair access, fair road to site; fair access; good roads within site | Good access, good roads to site; fair access, good roads within site | Good access, high standard road to site; good access within site |
| Total Points: 18<br>Point Value: | 0-3 | 4-6 | 7-10 | 11-14 | 15-18 |
| Environmental | Low esthetic factors that significantly lower quality | Average esthetic quality; factors exist that lower quality to minor degree | Above average esthetic quality; any limiting factors can be reasonably rectified | High esthetic quality; no factors exist that lower quality | Outstanding esthetic quality; no factors exist that lower quality |
| Total Points: 20<br>Point Value: | 0-2 | 3-6 | 7-10 | 11-15 | 16.20 |

**TABLE 5-5**
**UDV POINT ASSIGNMENTS**
**LAKE OKEECHOBEE RECREATION RESOURCES**

| | Recreation | Availability | Carrying Capacity | Accessibility | Environmental | Total Points | UDV |
|---|---|---|---|---|---|---|---|
| **Possible Points** | 30 | 18 | 14 | 18 | 20 | 100 | |
| **Assigned Points** | | | | | | | |
| Hunting & Fishing | 25 | 14 | 11 | 12 | 16 | 78 | $6.64 |
| General Recreation | 15 | 10 | 10 | 10 | 15 | 60 | $5.83 |

Current Corps guidance for UDV (Economic Guidance Memorandum 97-3) includes tables to convert recreation point values into dollar-based unit day values. As shown in Table 5-5, the points assigned to hunting/fishing and general recreation for Lake Okeechobee convert to UDVs of $6.64 and $5.83, respectively. These values were applied to the 1996 total visitor hours (64,503,500) in Table 5-3 with 28% of the total hours (i.e., 18,060,980 hours or 3,612,196 user days) assigned to hunting and fishing and 72% (i.e., 46,442,520 hours or 9,288,504 user days) assigned to general recreation. As a result of this procedure, the total value of recreation at Lake Okeechobee in 1996 was estimated at $78,151,409, calculated as [(3,612,196*$6.64)+( 9,288,504*$5.83)].

## 5.7 POTENTIAL EFFECTS OF ALTERNATIVE REGULATION SCHEDULES

The potential effects of the alternative regulation schedules on the quality and quantity of recreation depends on the sensitivity of existing recreation facilities and activities to changes in lake levels. No additional facilities are being contemplated as part of the LORSS project. In the case of the Lake Okeechobee Waterway, the quantity of recreation activities primarily refers to the ability of visitors to access the lake's recreation resources. The quality of recreation activities refers to how much enjoyment or satisfaction those activities produce. Finally, there are recreational safety issues that also may be sensitive to changes in lake levels.

### 5.7.1 Quantity Of Recreation Participation

Fluctuations in lake levels can affect the quantity of recreation participation on Lake Okeechobee. As an indicator of the sensitivity of recreation to lake levels, lake levels (measured to two decimal places) are posted daily on the front pages in newspapers of lakeside communities, such as the Clewiston News. Low lake stages can affect lake recreation in two principal ways. First, lake levels determine where boaters and fishermen can go on the lake. Specifically, access to much of the lake's littoral zone, which occupies approximately 25% of the lake area, can be reduced during low lake stages. According to discussions with local boaters, many fishermen and boaters will not go out on the lake when lake levels are very low (e.g., below 11 feet NGVD), since access to many fishing locations is not possible. However, the difficulties faced by boat fishermen during very low lake levels are somewhat offset by increased opportunities for anglers to wade from shore.

Second, some of the boat ramps on Lake Okeechobee would be inoperable at extremely low lake levels (i.e., below 10 feet NGVD). However, the depths of the lake at these extremely low lake stages would probably curtail boating activity before lake access via the ramps became a problem, particularly on the western side of the lake. The ramps at Corps recreation sites along the waterway typically extend from 9' to 21.5' NGVD. In addition, these specifications are recommended to state and local governments when they construct or rehabilitate boat ramps on the waterway. Discussions with boaters launching from the ramps on this waterway indicated that two feet of water is required at the bottom of the ramp to launch the small (bass) fishing boats that are typically used on Lake Okeechobee.

The spot soundings of boat ramps conducted as part of this study identified some boat ramps that were sensitive to lake levels. These soundings were taken at the lower end of the ramps and are presented in Appendix D. Four ramps have terminus depths below 5 feet; nine ramps had terminus depths between 5 and 7.5 feet; and five ramps had depths in excess of 7.5 feet. The lake stage at the time of the soundings was 15.2 feet NGVD. Therefore, some of the ramps would be inoperable at the lowest lake levels (below 10 feet NGVD). This could potentially inconvenience some ramp users, but they could access the lake via nearby substitute ramps.

An issue that is related to recreational access to Lake Okeechobee is the control of exotic plants in and around the lake. Many of the boat trails on the western side of the lake are already choked with aquatic vegetation. There is a variety of native and non-native aquatic vegetation in the lake. Some of these species reproduce at prolific rates. Lower lake levels compound the problem of aquatic plant infestation, since they further reduce access to the lake for fishing or boating. The Corps of Engineers and the SFWMD are cooperating in a program to control exotic aquatic and emergent species around the lake. From FY1992 to FY1997 the average expenditures on this program were $783,747 annually. According to the program managers, it is not possible to estimate the potential economic effects of implementation of the alternative restoration plans on the aquatic plant control program, for several reasons. First, there are multiple species targeted by the aquatic plant control program. High and low lake stages can have counterbalancing positive and negative effects on different exotic species. On a year-to-year basis, the problems with exotic plants depend on a complex interaction of climatic conditions, water temperature, and water levels. When water levels are high, exotic emergent vegetation is inundated and killed. When water levels are low, exotic emergent and aquatic vegetation is exposed and the plants dry and can be cleared using controlled burning. Low lake levels also improve access to the exotic melaleuca trees in the lake for "hack and squirt" control using a combination of cutting and pesticide treatment.

### 5.7.2 Quality Of Recreation Activities

The quality of recreation on the Lake Okeechobee Waterway is also subject to fluctuations in lake levels. Of the various lake-related recreation activities, sportfishing may be the most sensitive to changes in lake levels.

Fluctuations in lake stage have complex effects on fish stocks in Lake Okeechobee. Prior to 1900, Lake Okeechobee was clear with a sandy bottom. Lake stages varied with the season as overflow from the lake fed the southward sheetflow into the Everglades. However, construction of the levee system around the lake eliminated lake overflow and facilitated backpumping of nutrient-rich water from the Everglades Agricultural Area. In the last 30 years, rising nutrient levels have degraded water quality in the lake, and the lake has become increasingly eutrophic. More than one-half of the lake bottom is now covered with mud. In addition, periodic increases in lake stages – made possible by the levee system – have diminished the habitat quality of the littoral zone.

Under natural conditions, the variations in lake stages supported a diversity of plant communities in the littoral zone, providing high-quality fish and wildlife habitat. A given stage of Lake Okeechobee can have both positive and negative effects on fish and wildlife habitat. On the positive side, low lake stages:

- Allow muck to consolidate on the exposed lakebed thereby improving water quality and benthic habitat;
- Permit emergent vegetation to extend further into the lake, cleansing the water column; and,
- Enable the GFWFC to conduct controlled burning of exotic (i.e., non-native) species such as torpedo grass, hydrilla, and cattails; and allowing native plants to recolonize the area.

On the negative side, low lake stages can:

- Reduce access of fishermen to the lake, and
- Kill desirable aquatic vegetation, such as bullrush and eelgrass (although undesirable exotics are also killed when their habitat is drained).

High lake stages also have mixed effects. On the positive side, high lake stages are desirable since they kill undesirable exotic vegetation, such as hydrilla. On the negative side, desirable aquatic vegetation are also adversely impacted by high lake stages.

The ecological effects of changes in lake stages must be evaluated from both the short-term and long-term perspectives. For example, recreational fishing may suffer in the short term when lake stages are low, since the water is warmer and many gamefish are forced from shallow to deep water. However, longer term benefits to fishing from the drawdown can be realized the following year as fish stocks increase due to habitat improvements. Similarly, high lake stages may increase fishing in the short term by allowing better access to the lake, but the inundation of the littoral zone may have adverse effects on fishing the following year as a result of its diminished function as a fish nursery.

The SFWMD has established a Lake Okeechobee Littoral Zone Technical Group to monitor and assess the ecological condition of the lake's littoral zone, specifically the plant communities and their attributes as fish and wildlife habitat. The Group consists of aquatic scientists from the Federal, state, and private sectors. The Group has been evaluating the decline in the habitat quality of the littoral zone as manifested by: (1) loss of habitat for wading birds and waterfowl feeding, (2) decline in spikerush and beakrush communities that serve as nursery areas for young gamefish, (3) reduction in number of willows, which serve as rookery sites for wading birds and endangered snail kites, and (4) increase in torpedo grass and cattails which form dense monotypic stands that preclude foraging by birds and (when inundated) support low dissolved oxygen levels.

Among the causal factors for the ecological decline of the littoral zone are excessive fluctuations in lake stage, including the extent and duration of the fluctuations. From an ecological perspective, Lake Okeechobee lake stages are generally higher than desirable during the wet season (June through August) and generally lower than desirable during the dry season (October through March). While some lake stage fluctuations are desirable for purposes of fish and wildlife habitat, the net positive effects begin to erode when the fluctuations inundate or expose the littoral zone to the point of causing short-term and long-term stress on desirable fish and wildlife habitat.

Table 5-6 presents the simulated effects of the alternative restoration plans on Lake Okeechobee stages. For both the 1990 and 2010 scenarios, the simulated performances of the alternative regulation schedules using the first stage measure in this table (i.e., number of times stage less than 12' for more than one year) are equivalent. However, for the second measure (i.e., number of times stage less than 12' for more than 100 days), the HSMREC schedule is expected to significantly outperform the other regulation schedules. The HSMREC schedule is the only regulation schedule that is expected to represent an improvement over the without-project condition (i.e., Run25) with respect to this stage measure.

**TABLE 5-6**
**SIMULATED EFFECTS OF ALTERNATIVE REGULATION SCHEDULES ON LAKE OKEECHOBEE STAGES**

| Stage Measures | Scenario | Run25 | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|---|---|
| Number of times lake stage < 12' NGVD for > 1 year | 1990 | 1 | 1 | 1 | 1 | 1 |
| | 2010 | 1 | 1 | 1 | 1 | 1 |
| Number of times lake stage < 11' NGVD for > 100 days | 1990 | 2 | 2 | 2 | 1 | 2 |
| | 2010 | 3 | 5 | 3 | 2 | 4 |

Fishery biologists of the Florida Game and Fresh Water Fish Commission and sport fisherman on the lake indicate that low lake levels reduce the quantity and quality of the lake's littoral zone and thereby adversely affect critical spawning habitat. Conversely, high water levels on Lake Okeechobee can also impact the sport fishery by inundating the littoral zone of the lake. As discussed in Chapter 1, concerns about the effects of high water levels in the littoral zone on fish and wildlife – especially bird – habitat was one of the reasons that the LORSS was initiated. In general, the alternative schedules were designed to have fewer high lake stages than the current regulation schedule.

These high and low water considerations affect fishing on a monthly and yearly basis. There are also short-term considerations regarding whether the fish are "biting". Local fisherman report that the quality of the fishing declines significantly when lake levels get low, water temperatures rise, and dissolved oxygen levels fall. Discussions with sport fishermen on Lake Okeechobee yield a variety of opinions regarding the critical threshold when lake levels begin to affect the quality of fishing. In general, this threshold was reported to be approximately 14 feet NGVD.

The relationship between quality of fishing and lake levels has several qualifying factors. First, when low lake levels occur is important relative to the quality of fishing for particular sportfish at different times of the year. As indicated in Appendix E, the quality of fishing for particular species varies with the seasons. If low water occurred at a time when the fishing was not particularly good, the effects of the low water on fishing would be less, relative to other times of the year. A second qualifying factor is that low lake levels do not affect the quality of fishing for all sport species. While the quality of bass fishing may suffer as access to the lake's littoral zone is reduced, crappie fishing may be relatively unaffected, since they are usually caught in deep water.

### 5.7.3 Recreational Safety

Recreational hazards on Lake Okeechobee can be exacerbated by lower lake levels. As mentioned in Chapter 4, the potential for vessels to run aground increases as lake levels fall. The hazards to recreational navigation are greater than for commercial traffic, since commercial traffic generally follows designated channels, and recreational boaters move freely around the lake. On most occasions, there are no injuries, and the boats are not damaged by the soft bottom of the lake. However, there are occasions where life and property are at risk, especially during inclement weather. Long exposures to large waves can severely damage or destroy grounded vessels, leaving boaters at risk. Based on conversations with Corps operations personnel who are often called upon to assist grounded vessels, groundings in lake levels above 12.5 feet NGVD are infrequent, perhaps several groundings per month. However, below 12.5 feet NGVD, the frequency of groundings increases substantially, to as many as several groundings per day. The timing of the low lake levels is again a critical factor with respect to this safety issue. During the winter months, when tourist activity is highest, there are a large number of vessels on the lake, many of the operators are relatively inexperienced, and the likelihood of groundings is higher.

Another recreational safety issue that is affected by lake level fluctuations is wave action on Lake Okeechobee. Even at its highest levels, the lake is subject to hazardous wave action, since it is so shallow. According to discussions conducted with local boaters, the wave action on the lake substantially increases as lake levels drop, increasing the risk to recreation vessels.

## 5.8 ASSESSMENT

There are a variety of issues regarding recreational quantity and quality that are sensitive to changes in lake levels. These include access of boaters and fishermen to the lake, movement around the lake, the quality of their recreation experience, and their safety while participating in these recreational activities. In general, the quantity and quality of recreation on Lake Okeechobee is reduced as lake levels fall below 13 feet NGVD. it is expected that the lake will experience low levels under both with- and without-project conditions. However, the incremental differences associated with the alternative plans are expected to be insignificant with respect to recreation on this waterway.

A scenario was constructed, using available information, to assess the economic sensitivity of recreation to changes in lake levels. The output of the SWFMM model (see Figure 4-1) was used to estimate the frequency of undesirable stage events that could affect recreation on the lake. As shown in Table 5-6, the SWFMM runs conducted for the LORSS study contained two performance indicators on lake stage fluctuations: 1) number of events where lake stages fell below 12 feet NGVD for a period of more than 1 year; and 2) number of events where lake stages fell below 11 feet NGVD for a period of more than 100 days.

As discussed previously in this chapter, the quality and quantity of recreation declines when lake levels fall below 13 feet NGVD. Therefore, the SWFMM performance measure of the frequency of stage events less than 12 feet would a useful indicator of recreation impacts. However, the SFWMM estimates that the frequency of this event would be the same (1 occurrence over the 31-year simulation period) for both the without project condition (current regulation schedule) and with project condition (the alternative regulation schedules).

Therefore, another performance measure, the number of times stages fell below 11 feet NGDV for more than 100 days, was used to estimate recreational impacts. The number of low-stage events estimated over the 31-year simulation period was divided by 31 to estimate the probability of occurrence during a given year. Unit day values were re-computed for low lake stage periods for both hunting/fishing ($5.60) and general recreation ($4.72), to account for the decline in the quality of the recreational experience. The lower UDVs were then applied to the number of recreation user days anticipated to occur during low stage periods during a given year for both the current regulation schedule and the three alternative regulation schedules. The total annual values of recreation for the with- and without-project conditions were then calculated.

The annual differences between the with- and without-project conditions were calculated as follows: Run22AZE (-$435,173), WSE (-$217,586), COEREC (no change), and HSMREC (+$217,586). The negative values of Run22AZE and WSE suggest a decline in recreation benefits resulting from the increased frequency of low stages relative to the current regulation schedule. Conversely, the positive value of HSMREC suggests an improvement over the current schedule.

This scenario provides a rough approximation of the value of recreational impacts associated with extremely low lake level conditions. It may be the case, however, that the majority of recreation impacts would occur from more frequent, less severe, low lake level conditions. For example, the frequency of lake levels below 13 feet for more than 100 days would no doubt be greater than the frequency of events below 11 feet, and these less severe events could also impact the quantity and/or quality of recreation on Lake Okeechobee. In addition, this analysis focuses on the short-term recreation impacts of the alternative regulation schedules. It does not reflect the important role of a healthy littoral zone in maintaining the long-term health of the fishery.

# 6. COMMERCIAL FISHING

## OVERVIEW

Lake Okeechobee is home to an active commercial fishing industry. This includes several different types of commercial fishing operations and landside support activities, such as marinas and fish houses, which purchase the catch for wholesale and retail distribution. Large scale commercial fishing began in Lake Okeechobee around 1900 with the use of haul seines as primary gear, although trotlines, pound nets, and wire traps were also utilized. Catfish were the most commonly sought species by commercial fishermen. Other species such as bluegill, redear sunfish, and black crappie, as well as largemouth bass and mullet were also taken.

In 1916 the Florida Legislature imposed the first regulation on the industry, including a four-month closed season on haul seines, a maximum haul seine length, and a minimum haul seine mesh. Despite these initial regulatory efforts, commercial catches waned, due in part to over-fishing and in part to man-made changes in the lake. The levee on the southern shore of the lake prevented fish from entering adjacent marshes to spawn. Additionally, the emerging sport fishing industry began to push for increased regulation of the commercial fishing industry, claiming that commercial harvesting of game fish, particularly by haul seining, was detrimental to game fish populations. As a result, commercial fishing became increasingly regulated throughout the 1950's, with stronger restrictions on commercial harvest of game fish and limits on the use of commercial gear.

In 1976, the Florida Game and Freshwater Fish Commission authorized a commercial fishing program with the joint goals of improving lake water quality and restoring the sport fishery. The Commission recognized that commercial fish removal was a practical tool to improve the structure of game fish populations, as well as to remove nutrients (nitrogen and phosphorus) from the lake. The commercial harvest and sale of freshwater game fish (except black bass and chain and redfin pickerel) and the use of haul seines and trawls were approved. Initially, 40 haul seine permits and 200 trawl permits were issued. To avoid conflicts with popular sport fishing areas, haul seines and trawls were prohibited from operating within one mile of emergent (shoreline) vegetation.

In 1981, a severe drought resulted in historically low water levels in Lake Okeechobee. The lake's littoral zone was almost entirely drained, forcing fish populations from the shallows into deeper, open water. Widespread concern that the commercial fishing industry would over-harvest the dislocated fish populations led the Commission to temporarily suspend the use of haul seines and trawls for the harvest of game fish. In November 1982, the harvest and sale of some game fish (primarily bluegill and redear sunfish) and the operation of 10 haul seines were re-authorized. Trawl permits and the commercial harvest and sale of black crappie were not re-authorized.

Except for a 1995 state-wide ban on the commercial harvest of striped mullet, regulation of the commercial fishery has remained unchanged since 1982. Commercial fishing activity is banned on weekends and holidays, but otherwise occurs year round. The three primary gear types utilized on Lake Okeechobee are haul seines, trot lines, and wire traps. Haul seines are used to fish primarily for bream, although the by-catch (i.e., catfish, bullhead, shad and gar) must also be kept. Most of the current haul seiners operate out of Clewiston, although one operator is located in Pahokee. Daily haul seine harvests are accepted at four local fish markets: Jones Fish Company, Rudd's Fish House, Met's Mouth of the South, or B&R Fish House. Haul seine fishermen are responsible for filing weekly harvest reports with the Commission.

Commercial fishermen using trotlines or wire traps on Lake Okeechobee fish primarily for catfish. Gear regulations do not restrict the length of trotlines, however, each line is limited to a maximum of 500 individual hooks. Wire trap designs are restricted to two funnels at one end. Maximum trap dimensions must not exceed 7 feet in length or 32 inches in width. Additionally, the minimum mesh size for wire traps is one inch, and all wire traps must be submerged a minimum of five feet. Commercial harvests by trotliners are taken at two fish houses in Okeechobee (Stoke's and Dean's) and one fish house in Pahokee (Jones Fish Co.). Jones Fish Co. also accepts catch by wire trap. Fishermen using either wire traps or trotlines on Lake Okeechobee must have a state commercial fishing license. Because commercial fishing licenses are not specific to a particular fishery, the number of trotliners and wire trappers on Lake Okeechobee cannot be determined from license data. However, catch by gear type is recorded for Lake Okeechobee through reports that must be filed by each fish house with the Commission. Annual commercial fish harvests by species and gear type from 1986 to 1996 are contained in Table 6-1.

As part of the field investigation for this study, interviews with commercial fishermen, fish houses, and the Florida Game and Fresh Water Fish Commission were conducted to determine the scope of commercial fishing on Lake Okeechobee and assess its sensitivity to the potential changes in lake levels resulting from the alternative regulation schedules. Several fish houses were interviewed to determine current market prices (wholesale) in order to estimate commercial fishing income. The following average market prices were obtained from the fish houses: catfish ($.40/lb.), bream ($.90/lb.), shad ($.25/lb.), and tilapia ($.25/lb.). Based upon these prices the annual value of the wholesale commercial fishery is $2,326, 932.

In his 1987 study of the economic effects of commercial fishing on Lake Okeechobee, Bell (1987) estimated that there were a total of 210 jobs associated with commercial fishing in Lake Okeechobee. These included 190 jobs for fishermen using all types of gear and 40 landside jobs in local fish houses.

There is a continuing controversy in the Lake Okeechobee region regarding the compatibility of commercial fishing and sport fishing. Some sport fishermen accuse the commercial fishermen of degrading the sport fishery with excessive harvests. The Game and Fresh Water Fish Commission has conducted a variety of studies that suggest that commercial fishing actually benefits sport fishing by removing non-sport species and reducing nutrient levels in the lake that these species have absorbed. In general, the sport fishermen are skeptical, but the Commission has maintained that the sport fishery has thrived in recent years despite commercial fishing.

## TABLE 6-1
## COMMERCIAL FISH HARVEST (pounds)
## LAKE OKEECHOBEE, 1986-1996

| TROTLINE | White Catfish | Channel Catfish | Brown Bullhead | Yellow Bullhead | Bluegill | Redear Sunfish | Shad | Gar | Striped Mullet | Tilapia | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1986-1987 | 2,061,860 | 266,814 | 34,058 | 0 | | | | | | | **2,362,732** |
| 1987-1988 | 1,993,339 | 30,896 | 20,816 | 1,367 | | | | | | | **2,046,418** |
| 1988-1989 | 2,174,885 | 160,837 | 27,159 | 247 | | | | | | | **2,363,128** |
| 1989-1990 | 1,666,426 | 223,882 | 38,267 | | | | | | | | **1,928,575** |
| 1990-1991 | 1,495,038 | 350,641 | 45,448 | | | | | | | | **1,891,127** |
| 1995-1996 | 1,504,830 | 372,966 | 84,443 | 2,293 | | | | | | | **1,964,532** |
| **HAUL SEINES** | | | | | | | | | | | |
| 1986-1987 | 202,399 | 78,527 | 133 | | 532,361 | 178,005 | 588,232 | 70,788 | 119,390 | | **1,769,835** |
| 1987-1988 | 386,633 | 27,489 | 1,664 | | 386,498 | 205,563 | 499,374 | 97,485 | 264,222 | | **1,868,928** |
| 1988-1989 | 320,384 | 22,362 | 9,647 | | 700,300 | 119,218 | 361,834 | 86,803 | 176,294 | | **1,796,842** |
| 1989-1990 | 295,981 | 162,051 | 72,497 | | 717,250 | 272,364 | 521,245 | 100,766 | 167,388 | | **2,309,542** |
| 1990-1991 | 430,064 | 251,862 | 25,970 | | 875,319 | 265,253 | 409,061 | 252,407 | 164,257 | | **2,674,193** |
| 1995-1996 | 877,047 | 138,433 | 107,161 | | 625,329 | 276,735 | 1,557,969 | 295,190 | | 136,308 | **4,014,172** |
| **WIRE TRAP** | | | | | | | | | | | |
| 1986-1987 | 38,751 | 188,033 | 33,310 | | | | | | | | **260,094** |
| 1987-1988 | 208,076 | 135,536 | 43,563 | 85 | | | | | | | **387,260** |
| 1988-1989 | 62,182 | 11,173 | 17,353 | 1,792 | | | | | | | **92,500** |
| 1989-1990 | 34,700 | 22,349 | 6,109 | 23 | | | | | | | **63,181** |
| 1990-1991 | 52,732 | 7,189 | 2,094 | | | | | | | | **62,015** |
| 1995-1996 | 20,467 | 8,509 | 4,401 | | | | | | | | **33,376** |
| **ALL GEAR** | | | | | | | | | | | |
| 1986-1987 | 2,303,010 | 533,374 | 67,501 | | 532,361 | 178,005 | 588,232 | 70,788 | 119,390 | | **4,392,661** |
| 1987-1988 | 2,588,048 | 193,921 | 66,043 | 1,452 | 386,498 | 205,563 | 499,374 | 97,485 | 264,222 | | **4,302,606** |
| 1988-1989 | 2,557,451 | 194,372 | 54,159 | 2,039 | 700,300 | 119,218 | 361,834 | 86,803 | 176,294 | | **4,252,470** |
| 1989-1990 | 1,997,107 | 408,282 | 116,873 | 23 | 717,250 | 272,364 | 521,245 | 100,766 | 167,388 | | **4,301,298** |
| 1990-1991 | 1,977,834 | 609,692 | 73,512 | | 875,319 | 265,253 | 409,061 | 252,407 | 164,257 | | **4,627,335** |
| 1995-1996 | 2,402,343 | 519,908 | 196,005 | 2,293 | 625,329 | 276,735 | 1,557,969 | 295,190 | | 136,308 | **6,012,080** |

Source: Florida Game and Freshwater Fish Commission.

## 6.1 POTENTIAL EFFECTS ON COMMERCIAL FISHING IN LAKE OKEECHOBEE

Changes in lake levels associated with the alternative regulation schedules could impact commercial fishing operations and/or the stocks of commercial fish. Fluctuations in lake levels could also potentially affect landside support services. The purpose of this analysis is to determine whether commercial catch or operating costs would be affected by the alternative regulation schedules and, if so, to quantify the NED effects of these changes.

The NED account registers changes in net income from commercial fishing operations. Net income changes result from either changes in the size of the catch (net revenues) and/or changes in the cost of catching the fish (net operating costs). The LORSS alternative regulation schedules are not anticipated to affect the overall size of the Lake Okeechobee fishery or the amount of the commercial fishing catch. In fact, the single greatest determinant in the size of the fishing catch (and net fishery revenues) are the complex series of operational restrictions placed on the fishery by Florida Game and Fresh Water Fish Commission.

The cost of catching fish (net operating costs) could potentially be changed if the lake's regulation schedule were modified, however. Interviews with commercial fishermen on Lake Okeechobee were conducted to: (1) evaluate the operations and economics of commercial fishing on the lake and (2) determine the sensitivity of commercial fishing to changes in lake levels associated with the alternative regulation schedules. The interviews with commercial fisherman were conducted with haul seiners. Questions about commercial fishing with trotlines and wire traps were answered by representatives of the Florida Game and Fresh Water Fish Commission field office in Okeechobee, on the north side of the lake.

The total number of haul seine permits are limited to 10 in order to keep fish yields sustainable. The profitability of the haul seine operations are indicated by the long waiting list for permits reported by the Game and Fresh Water Fish Commission. Although some of the vessels are larger, most of the haul seine operations use vessels with lengths of approximately 35 feet and drafts of four to five feet, depending on the vessel and the size of the catch in the hold. In general, the seiners prefer low lake levels to high lake levels. The reason is based on their equipment. The seines are set by driving a metal pole into the lake bottom with one end of the seine attached. The fishing boat then motors away laying the seine in a large arc. The boat slowly completes the circle as it returns to the pole. Another pole is driven adjacent (approximately one foot distance) to the first. The net is pulled through the space between the poles, slowly closing it around the enclosed fish. The fishermen report that deeper waters are problematic for haul seines, because they require larger poles which are more difficult to drive into the lake bottom. They also indicated that they do not like to fish in deep waters of the lake, since the nets will sink into the muddy bottom. It is possible for haul seines to be used at depths over 20 feet, but some fishermen would need to purchase new nets, and the costs are compounded by the physical challenge of using haul seines in deeper water.

The haul seiners prefer lake levels that are in the 13 to 14 foot NGVD range. Lower lake levels constrain their movements around the lake. Higher lake levels make their gear more difficult to use and induce the fish to move into shallow waters that are inaccessible to commercial fishermen. In addition, the commercial fishermen recognize that very high or very low lake levels inundate or drain the littoral zone which is critical to fish spawning. The higher water temperatures of low water were also cited as adversely impacting spawning.

The haul seiners operate year round. The haul seine licenses require that they fish at least 120 days per year. They apparently do not fish much more than this due to adverse weather considerations on the lake. If winds are in excess of 15 knots, the fishermen generally will not leave port, since waves on Lake Okeechobee are so problematic. The connection between increased wave formation and lower lake levels was also cited by these fishermen.

Fishermen who use trotlines and wire nets generally prefer high water conditions since they operate in the deeper waters of the lake to harvest catfish. Bell (1987) estimated that there were approximately 80 trotline fishermen operating on the lake. According to Game and Freshwater Fish Commission representatives, there are only a few fishermen who use wire nets, and they are required by their fishing licenses to have at least five feet of water overhead. They generally prefer water depths around 8 feet (which is the authorized channel depth in the lake at lake level 14.56 feet NGVD).

## 6.2 ASSESSMENT

In general, commercial fishing on Lake Okeechobee is not very sensitive to changes in lake levels. The operating draft of commercial fishing vessels are sufficiently shallow to allow access to Lake Okeechobee throughout the range of lake levels anticipated with the alternative regulation schedules. While fishermen seem to prefer lake levels in the intermediate range, most would prefer to have lower lake levels to higher lake levels.

In terms of the size of fish stocks, the ecological effects of the alternative regulation schedules could potentially affect the number of fish and mix of species in Lake Okeechobee. The alternative regulation schedules are all expected to improve habitat conditions in the lake's littoral zone by reducing the extent and duration of extreme lake stages relative to the future without-project condition. This would probably translate into an increase in the size of commercial fish stocks. The commercial fishermen interviewed indicated that very high or very low lake levels inundate or drain the littoral zone which is critical to fish spawning. The higher water temperatures during low water periods were also cited as adversely impacting spawning.

Despite the positive ecological effects of the alternative regulation schedules, it is unlikely that the resulting marginal increase in fish stocks will significantly affect the size of the commercial fish catch. The single greatest determinant of the size of the fishing catch (and net fishery revenues) is the complex series of operational restrictions placed on the fishery by GFWFC to promote a sustainable commercial harvest. These regulations are not expected to change between the with- and without-project conditions. It is unlikely that the GFWFC will allow a significant increase in the commercial harvest following implementation of the regulation schedules.

In terms of physical access to the fishery, the operating drafts of commercial fishing vessels on Lake Okeechobee are sufficiently shallow to access commercial stocks throughout the range of lake levels anticipated with the alternative regulation schedules. However, there may be some marginal benefits realized by reducing the costs of fishing operations, since fishermen seem to prefer lake levels in the intermediate range and the alternative regulation schedules are anticipated to moderate lake stage fluctuations.

Regulation of the fishery by the GFWFC appears to be the most significant determinant of both the size of the commercial catch and the net income of commercial fishermen. While the GFWFC has shown in the past (e.g., 1981) that it will modify the restrictions on the fishery in response to extreme changes in lake levels, it is not anticipated that any similar action would be taken in the foreseeable future. Commercial fishing on the lake currently appears to be at sustainable levels. Therefore it is unlikely that any regulatory changes would be made in response to the modest effects anticipated from implementation of any of the alternative regulation schedules.

# 7. COMMERCIAL AND RECREATIONAL FISHING IN THE CALOOSAHATCHEE AND ST. LUCIE ESTUARIES

## OVERVIEW

The alternative regulation schedules for Lake Okeechobee were formulated to keep lake levels low in the wet season (June to October) to provide flood and hurricane protection; and to keep levels high in the dry season (November to May) for water supply purposes. The lake has four principal outlets for discharging inflows received from its tributary waterways: (1) evaporation, which in the south Florida climate accounts for 70% of the lake's water loss, (2) the distributary canals that convey water southward to the LEC and the Everglades, (3) the Atlantic Ocean via the St. Lucie canal, and (4) the Gulf of Mexico via the Caloosahatchee River. The quantity, quality, and timing of the releases to the St. Lucie and Caloosahatchee estuaries are critical determinants of the diversity and productivity of those ecosystems. The purpose of this chapter is to interpret the economic consequences of the alternative regulation schedules. The potential economic consequences could be manifested through changes in the hydrologic regimes of the outlet waterways and resultant ecological effects on the estuarine ecosystems.

## 7.1 EFFECTS OF LAKE RELEASES ON ESTUARINE ECOLOGY

These two estuaries are highly productive ecosystems that exist at the interface between freshwater and seawater. The St. Lucie Estuary is a small estuary of approximately 6,000 acres located in Martin and St. Lucie counties. The North and South Forks, which constitute the inner estuary, converge at the City of Stuart where the river widens to one mile after passing beneath the Roosevelt Bridge. Approximately three miles east, the river bends to the south, extending to the southernmost extension of Sewell Point, a spit of land separating the St. Lucie River from the Indian River Lagoon to the east. At Sewell Point, both bodies of water empty into the Atlantic Ocean at the St. Lucie Inlet.

The Caloosahatchee Estuary is part of the southern portion of Charlotte Harbor, which includes the estuary, San Carlos Bay, Pine Island Sound, and Matlacha Pass. The estuary extends 29 miles from the W.P. Franklin Lock and Dam near Alva to Shell Point at its mouth in San Carlos Bay. San Carlos Bay, which is bounded by Sanibel Island and Pine Island, is located at the confluence of the river, Pine Island Sound, Matlacha Pass, and the Gulf of Mexico. The freshwater releases into the estuary are controlled by the Franklin Lock and Dam, which also serves as a barrier to salinity and tidal influences upstream.

The quantity, timing, and quality of freshwater inputs to estuaries are critical determinants of the structure and function of these ecosystems (Bulger et al., 1990). Freshwater flows provide critical functions and materials for estuaries, including:

- Nutrients for estuarine biota;
- Protection from predation by mature life stages that are intolerant of lower salinities or that are unable to find prey in naturally turbid estuarine waters;
- A range of salinity conditions for a variety of organisms with different requirements for growth and development; and

- Transportation and deposition of many estuarine-dependent larvae.

Relative to natural conditions, the releases from Lake Okeechobee and changes in their watersheds have significantly altered freshwater inputs to the St. Lucie and Caloosahatchee estuaries and have adversely affected the structure and function of these sensitive ecosystems. In general, the peak flows from the lake to these estuaries are higher than those under natural conditions, and the low flows are lower.

The changes in freshwater inputs to the estuaries have short-term and long-term effects on these ecosystems. The most immediate effect of these changes is the magnification of the natural fluctuations of salinity in these estuaries. Estuarine species evolved under conditions of naturally fluctuating salinity levels, but excessive fluctuations can stress these ecosystems. As described by Bulger et al. (1990), excessive salinity fluctuations can keep estuarine biota in constant flux between organisms which favor higher salinity and those which favor lower salinity. If the fluctuations are extreme, appropriate salinity conditions do not last long enough for organisms to complete their life cycle, and the diversity of organisms is reduced to those few species which can tolerate the dramatic salinity fluctuations.

Even moderate releases (such as in Zone B of the Run25 schedule) can transform these estuarine systems into freshwater habitats after a few weeks of sustained releases. The estuarine species are displaced or expire during extended periods of low or high salinity. In addition, continuous flow releases tend to create critically low benthic oxygen levels at the transition zone between freshwater and seawater. These ecosystem perturbations affect more than just estuarine species, since estuaries provide critical nursery habitat for marine (offshore) finfish and invertebrate species. These adverse effects provided the impetus for instituting the pulse releases contained in Zone C of the Run25 schedule.

In general, when regulatory releases are terminated, the salinity levels in these estuaries return to the normal range, and the ecosystems begin to recover. The estuarine species that were displaced or extirpated return or are replaced. The recovery period is commensurate with the rate and duration of the freshwater inputs to the estuaries.

Other longer-term effects of the regulatory releases from the lake on the St. Lucie and Caloosahatchee estuaries include sediment and nutrient effects. Both effects are related to the quality of the water releases from Lake Okeechobee, which contain suspended silt, clay, and organic material. Much of the suspended material settles onto the bottom of the St. Lucie Canal and the Caloosahatchee River during modest, nonregulatory releases. However, during regulatory releases – particularly the high release levels in Zone B and Zone A of the Run25 schedule– this material is resuspended and carried into the estuaries during the first few days of the release period.

Suspended material increases the turbidity of the water in the estuaries and blocks sunlight to seagrass communities in these estuaries. Some seagrass communities are smothered by the suspended material as it settles in the low-energy environment of the estuaries. Other seagrass communities are affected by the reduction in sunlight that results from increased turbidity. Nutrient effects result from the nitrates and phosphorus contained in the lake water which are resuspended by the release flows and stimulate primary production in the estuaries. Releases can imbalance nutrient cycling in these ecosystems, leading to algae blooms and subsequent declines in dissolved oxygen and further increases in turbidity.

The short-term and long-term ecological problems in these estuaries are not entirely attributable to the regulatory releases from Lake Okeechobee, however. These estuaries have perturbations from other sources that contribute to the stresses on these ecosystems. For instance, other estuarine tributaries deposit freshwater, sediments, and nutrients in these ecosystems, including heavy metals that are associated with agricultural pesticide use in the contributing watersheds.

## 7.2 FISHING AND OTHER ECONOMIC EFFECTS ON THE ESTUARIES

The ecological effects of the freshwater releases to the estuaries can lead to commercial and recreational fishing impacts. These potential economic effects are discussed below. There are other potential (non-fishing) economic effects from freshwater releases which are also associated with changes in estuarine water quality. These effects could include changes in (1) waterfront property values if water quality degradation is severe or sustained, (2) the quantity or quality of recreation (and tourism) if the releases discolor the water at beaches or if the releases contribute to algae blooms that limit beach access. These nonfishing effects are beyond the scope of this investigation, but they are current sources of concern to local residents and businesses who enjoy the estuaries and depend on tourists who come to use them. For example, in the spring of 1998 the City of Sanibel received complaints from residents and tourists about the water quality effects of freshwater releases down the Caloosahatchee River and into San Carlos Bay and the Gulf of Mexico.

## 7.3 REGULATORY RELEASE TARGETS FOR ESTUARIES

In response to the competing objectives of managing high stages on Lake Okeechobee and promoting the health of the St. Lucie and Caloosahatchee estuaries, the SFWMD has adopted salinity targets for these estuaries with associated high and low release targets. The release targets, expressed in cubic feet per second (cfs), comprise one set of performance measures used to evaluate the alternative regulation schedules (see Table 7-1). The measures are the number of months that SFWMM-simulated releases exceed target release levels. The low flow targets for the two estuaries are similar. High flow targets for the St. Lucie are significantly lower than for the Caloosahatchee, since the St. Lucie estuary is a much smaller receiving water body and therefore is more affected by high freshwater releases. For both estuaries, two performance measures for large releases from the lake have also been developed, incorporating quantity thresholds and duration criteria.

**TABLE 7-1**
**LOW FLOW & HIGH FLOW PLANNING TARGETS**
**ST. LUCIE AND CALOOSATCHEE ESTUARIES**

| ESTUARY | LOW FLOW | | HIGH FLOW | |
|---|---|---|---|---|
| | **Measure** | **Target** | **Measure** | **Target** |
| St. Lucie | Number of Months Mean Flow < 350 cfs | 50 | Number of Times Mean Flow > 1600 cfs for > 14 days | 13 |
| | | | Number of Times Mean Monthly Flow > 1600 cfs | 9 |
| | | | Number of Times Mean Monthly Flow > 2500 cfs | 3 |
| Caloosahatchee | Number of Months Mean Flow < 300 cfs | 60 | Number of Months Mean Flow > 2800 cfs | 22 |
| | | | Number of Months Mean Flow > 4500 cfs | 6 |

## 7.4 POTENTIAL EFFECTS ON FISHING IN ST. LUCIE ESTUARY

The potential economic effects of the alternative regulation schedules on fishing in the St. Lucie estuary depend on how the hydrologic changes affect the ecology of the estuary and on how the ecological changes translate into changes in commercial and recreational fishing. The economic effects on commercial fishing might include changes in the size of the catch or the cost of fishing operations. For guided sportfishing, the economic effects might include changes in the income of the professional fishing guides. For recreational anglers, economic effects could result from changes in the quantity or quality of recreational fishing experiences. As evident in the discussions below, the linkages between the hydrology, ecology, and economics of fishing in the St. Lucie Estuary are highly uncertain. Nevertheless, the hydrologic information generated through the SFWMM simulations does have economic implications for fishing in the estuary.

As part of this investigation, a variety of individuals, organizations, and institutions were contacted to identify pertinent studies and individuals with expertise on the effects of Lake Okeechobee releases on the St. Lucie Estuary. Contacts included:

- Florida Oceanographic Society;
- Marine Research Council;
- Harbor Branch Oceanographic Institute;
- St. Lucie Initiative;
- St. Lucie River Coalition;
- Florida Marine Research Institute;
- Florida Sea Grant;
- Martin County;
- Indian River Lagoon National Estuary Program;
- Treasure Coast Regional Planning Council; and
- SFWMD.

### 7.4.1 Profile of Commercial and Recreational Fishing in the St. Lucie Estuary

A profile of commercial and recreational fishing in the St. Lucie Estuary can be constructed using field information and data from state and national fishing databases. Unfortunately, much of the available information about commercial and recreational fishing in the estuary is contained in studies and data sets for much larger geographic areas.

There is very little, if any, commercial fishing in the St. Lucie Estuary. The use of gill nets in Florida coastal waters was banned in 1994. Interviews with local fish houses (i.e., retailers) indicate that their supplies do not come from the estuary. However, there may be low levels of commercial fishing for finfish (using rod and reel or cast nets) and for crabs. In Martin County, there are 271 saltwater products licenses and 44 permits for blue crab fishing. Crabbing activity in the estuary is believed to be small.

Although there is little commercial fishing within the estuary proper, the St. Lucie Estuary has important ecological connections with offshore commercial fish stocks. As explored in Nelson et al. (1991), some commercial species of finfish and invertebrates inhabit estuaries year-round; however, a large number of species only use estuaries during portions of their life cycle. Most of these latter species fall into four general categories:

- Diadromous species, which use estuaries as migration corridors and, in some instances, nursery areas;
- Species that use estuaries for spawning, often at specific salinity levels;
- Species that spawn in marine waters near the mouths of estuaries and depend on tidal- and wind-driven currents to carry eggs, larvae, or early juveniles into estuary nursery areas; and,
- Species that enter into estuaries during certain times of the year to feed on abundant prey and/or utilize preferred habitats.

In 1990, the Indian River Lagoon, which adjoins the St. Lucie Estuary, was included in the National Estuary Program (NEP). The NEP targets nationally significant estuaries for assessment and development of management plans that will substantially enhance their ecological quality. While the NEP studies on Indian River Lagoon suggest that the freshwater flows from the St. Lucie Estuary may not significantly affect the lagoon, they do provide insight to the ecology of the St. Lucie Estuary. In particular, the Indian River Lagoon studies identified 20 species of commercial finfish and 3 species of shellfish (blue crab, hard clam, and oyster) in the lagoon that are estuarine dependent. The estuarine-dependent finfish include:

- Atlantic sheepshead;
- Bluefish;
- Croaker;
- Drum, black;
- Drum, red;
- Flounders;
- Jack, crevalle;
- King whiting;
- Mackerel, spanish;
- Menhaden;
- Mullet, silver;
- Mullet, striped;
- Permit;
- Pompano;
- Snapper, mangrove;
- Snapper, mutton;
- Snapper, yellowtail;
- Seatrout, spotted;
- Spot; and,
- Tripletail

Nelson et al. (1991) noted that the estuaries on Florida's east coast include large numbers of tropical Caribbean fauna. In addition, they determined that the number of species – including adults, juveniles, and larvae – in southeastern estuaries varies by season and by salinity zone. Estuarine utilization for all life stages is highest in summer and lowest in winter. The number of species present as larvae reaches a peak in April in the tidal freshwater, mixing, and seawater zones. In contrast, the numbers of juveniles and adults in the three zones peak during the summer months. In any given month, more species utilize these estuaries as juveniles than at any other life stage. Some common species, such as bluefish and gray snapper, are primarily found in the estuary as juveniles and adults, with spawning, eggs, and larval development occurring offshore. Other species, such as snook and tarpon, are tolerant of a wide range of salinity levels. Seasonal variations in species composition implies that the timing – as well as the quantity – of freshwater releases to the St. Lucie Estuary are critical determinants of their potential effects on the estuarine ecology.

The Florida Department of Environmental Protection (FDEP) maintains the Florida Marine Fisheries Information System, a database of commercial fish landings. In this database, the St. Lucie Estuary is located within the Ft. Pierce fishing area, which extends approximately from Jupiter to Melbourne. Summaries of the 1993-1997 inshore commercial landings for this fishing area are presented in Table 7-2. Inshore is defined as within three miles of the coast. The summaries include finfish, invertebrates, and bait shrimp. No shrimp landings were reported. The poundage, trips, and value of finfish have varied widely over the last five years, with values ranging from one-half million dollars to more than one million dollars. In contrast, the invertebrate landings showed a steady increase in all three categories.

The Ft. Pierce inshore waters landings data is complemented by Table 7-3, which contains the top eight commercial landings (by weight) in Martin County during 1997. The ten listed species each account for at least two percent of the total county catch by weight (2,054,136 pounds). Together, they account for 82% of the total catch. Most of the species on this list reside in estuarine habitat for at least part of their life cycle.

**TABLE 7-2**
**COMMERCIAL LANDINGS**
**FT. PIERCE INSHORE WATERS**
**1993-1997**

| | | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Finfish | Pounds | 1,766,741 | 2,077,588 | 1,065,894 | 843,586 | 772,355 |
| | Trips | 5,045 | 6,353 | 4,860 | 6,063 | 4,787 |
| | Value | $793,107 | $984,043 | $664,367 | $613,413 | $523,118 |
| Invertebrates | Pounds | 41,066 | 72,815 | 86,301 | 76,811 | 93,778 |
| | Trips | 496 | 1,443 | 2,671 | 2,630 | 1,393 |
| | Value | $84,809 | $208,860 | $640,030 | $862,998 | $1,168,742 |
| Bait Shrimp | Pounds | 1,022 | 0 | 0 | 0 | 0 |
| | Trips | 13 | 0 | 0 | 0 | 0 |
| | Value | $2,452 | 0 | 0 | 0 | 0 |

Source: Florida DEP, 1997

**TABLE 7-3**
**RANKED COMMERCIAL FINFISH LANDINGS BY WEIGHT**
**MARTIN COUNTY**
**1997**

| SPECIES | POUNDS | PERCENT OF TOTAL CATCH |
|---|---|---|
| Thread Herring | 529,447 | 26% |
| Mackerel, Spanish | 274,702 | 13% |
| Sardines | 272,368 | 13% |
| Mackerel, King | 134,820 | 7% |
| Shark | 123,687 | 6% |
| Scad, Bigeye | 88,975 | 4% |
| Mullet, Black | 88,795 | 4% |
| Spot | 76,135 | 4% |
| Bluefish | 51,257 | 2% |
| Porgies | 37,310 | 2% |

Source: Florida Marine Fisheries Information System

The 1997 commercial invertebrate landings for Martin County were relatively small. They included 5,245 pounds of blue crabs, 6,174 pounds of stone crabs, and 11,105 pounds of spiny lobsters. There were no shrimp landings reported in Martin County for 1997.

The St. Lucie Estuary also supports guided sportfishing and recreational fishing. According to interviews with local professional sportfishing guides, there are approximately 12 guides who operate in this estuary on a full-time basis. Charters typically fish for tarpon, spotted seatrout, snook, and red drum. Assuming that the guides charge an average of $300 per day, guided sportfishing in the estuary would have an approximate annual value in excess of $800,000. The guides indicate that while the majority of their charters consist of tourists, there are also a significant number of charters by Florida residents. Cited percentage ratios of resident/tourist charters were 40/60 for much of the year and 20/80 during the tourist season (i.e., winter and early spring).

Fishing in the St. Lucie Estuary is also popular with local anglers. Bell et al. (1982) have estimated that the overall economic value of recreational fisheries to a region can be as much as six times that from commercial fisheries. Unfortunately, no current participation rates for recreational fishing in the estuary could be identified during this investigation. However, a general impression of recreational fishing in the St. Lucie Estuary can be constructed using the following studies of recreational fishing in areas that include the estuary.

1. In a 1979 creel census of recreational anglers in the St. Lucie Estuary, Van Os et al. (1980) estimated that 338,797 fish were caught (446,820 pounds). The most abundant fish were sea catfish, but bluefish dominated the catch by weight.

2. The National Survey of Recreational Fishing conducted by the National Oceanic and Atmospheric Administration (NOAA) has collected recreational fishing data for the east and

west coasts of Florida. The 1996 recreational landings for the east coast of Florida are presented in Table 7-4 for those species that account for at least one percent of the total catch. Since the survey is for creeled fish, catch-and-release statistics are not available. For some gamefish, such as tarpon, catch-and-release accounts for the entire recreational fishery.

3. Bell et al. (1982) estimate that 61.5% of recreational fishing trips are within brackish coastal waters or within 3 miles of shore, where fisheries stocks are largely dependent on estuaries

4. Nelson et al. (1991) describe bluefish, gray snapper, spotted seatrout, spot, black drum, red drum, and gulf flounder as among the species that are abundant in the adjacent Indian River Lagoon, and by inference, in the St. Lucie Estuary.

5. Milon and Thunberg (1993) conducted a state-wide survey of resident anglers. They estimated that, on a statewide basis, resident anglers make 8.7 fishing trips per year and that 56% of trips involved private boats. For Florida Marine Fisheries Commission Region 6, which includes the St. Lucie Estuary, Milon and Thunberg estimated over 65% of the total fishing effort was expended in near-shore waters or within the estuary or lagoon complex. Their findings suggest that over 90% of the recreational fishing by Florida residents in Region 6 is done by people who reside in the lagoon watershed. In addition, their surveys indicate that sea trout, snook, and red drum are the most popular species with anglers, pursued by 48% of the anglers who expressed species preference. The survey results suggest average statewide daily expenditures by resident anglers of $114.81, with annual expenditures of $576.49 per fisherman. This is consistent with Bell's estimate of $508.97 spent per fisherman on recreational fishing during 1982.

6. Bell (1993) investigated fishing by tourists to Florida. He estimated that of those tourists visiting Florida, 16.5% had engaged in saltwater fishing in the last year. However, 90% of the tourist anglers do not come primarily to fish, and two-thirds of these anglers have no target species. The tourists spend approximately $110 per day while fishing.

7. Bell (1992) investigated the potential changes in tourist visitation resulting from adverse effects on recreational beaches and fisheries. He noted a statewide decline in catch per trip from 5.8 to 4.5 fish/trip from 1979-1990. However, during the same period, he found no relationship between changes in tourism and changes in the catch rates of recreational saltwater fishing in the state.

**TABLE 7-4**
**RECREATIONAL LANDINGS**
**EAST COAST OF FLORIDA**
**1996**

| Species | Landings | Percent |
|---|---|---|
| Saltwater catfishes | 1,016,102 | 4% |
| Spot | 878,155 | 3% |
| Jack, crevalle | 840,862 | 3% |
| Mullets | 752,765 | 3% |
| Other fishes | 696,490 | 3% |
| Snapper, gray | 584,592 | 2% |
| Drum, red | 385,577 | 1% |
| Pinfishes | 358,850 | 1% |
| Kingfishes | 355,793 | 1% |
| Sheepshead | 350,996 | 1% |
| Other grunts | 205,466 | 1% |
| Herrings | 188,775 | 1% |
| Bluefish | 131,526 | 1% |

Source: NOAA. National Survey of Recreational Fishing. 1997.

### 7.4.2 Hydrologic Changes Associated With Alternative Schedules

The SFWMM-simulated hydrologic effects of the alternative regulation schedules on the St. Lucie Estuary are presented in Table 7-5. The first two measures compare the simulated frequencies of high-flow, low-salinity events attributable to local basin runoff and to regulatory releases. Regarding the second performance measure in Table 7-5 (the number of times mean flow exceeds 1600 cfs for at least 14 days due to regulatory releases), all of the alternative regulation schedules are expected to exceed the performance (i.e., reduce the number of events) of the 1990 and 2010 without-project conditions (i.e., Run25). Among the alternative schedules, the COEREC alternative is expected to yield the fewest number of these high-flow events. Regarding the third and fourth measures (i.e., number of times of high mean monthly flows), the alternative regulation schedules are also anticipated to result in fewer high-flow/low-salinity events than the 1990 and 2010 without-project conditions. For these measures, the most desirable alternative regulation schedules differ. For the third measure, Run22AZE was most desirable under the 1990 and 2010 scenarios. For the fourth measure, WSE was most desirable under the 1990 scenario, and this schedule was equivalent to the COEREC in terms of desirability under the 2010 scenario.

**TABLE 7-5**
**SIMULATED HYDROLOGIC PERFORMANCE OF ALTERNATIVE REGULATION SCHEDULES**
**ST. LUCIE ESTUARY**

| Salinity Measure | Scenario | Run25 | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|---|---|
| Number of times 14-day average flow > 1600 cfs for > 14 days from local basins* | 1990 | 59 | 57 | 36 | 59 | 58 |
| | 2010 | 55 | 54 | 54 | 55 | 55 |
| Additional number of times 14-day average flow > 1600 cfs for > 14 days from regulatory releases | 1990 | 53 | 39 | 39 | 36 | 43 |
| | 2010 | 37 | 24 | 23 | 25 | 30 |
| Number of times mean monthly flow > 1600 cfs (target = 9) | 1990 | 65 | 60 | 61 | 61 | 63 |
| | 2010 | 56 | 49 | 54 | 50 | 54 |
| Number of times mean monthly flow > 2500 cfs (target = 3) | 1990 | 30 | 26 | 27 | 25 | 24 |
| | 2010 | 26 | 22 | 20 | 24 | 20 |

* mean flows are attributable to lake releases and St. Lucie basin drainage

In Table 7-5, the expected performances of the with- and without-project conditions under the 2010 scenario generally exceed those under the 1990 scenario. As discussed in Chapter 1, the 1990 and 2010 scenarios are not directly comparable. The most important comparison to be made in this table are between the with- and without-project conditions within the 1990 and 2010 scenarios.

### 7.4.3 Potential Ecological and Economic Effects of Hydrologic Changes

There has been long-standing concern about the effects of regulatory releases on the St. Lucie Estuary. More than 20 years ago, conferences were sponsored by the Florida Oceanographic Society to discuss the ecological impacts of the regulatory releases. Over the years, the level of local awareness of the issues surrounding the ecological effects of the releases has varied in accordance with the release levels.

In 1998, a number of local interests expressed concern regarding the effects of the regulatory releases. Following the extremely wet spring induced by a strong El Nino event, high lake levels required Zone A releases into the St. Lucie Estuary under the Run25 schedule, with release volumes as high as 7,500 cfs. The brackish estuary was quickly transformed into a freshwater estuary, and the accumulated sediment on the canal bottom was quickly transported and deposited on the estuary benthos. The concerns of local residents was heightened when deformed mullet and gamefish with lesions were observed in the estuary. Water samples revealed the presence of *Cryptoperidiniopsis*, a marine algae, in the estuary. *Cryptoperidiniopsis* is being investigated by FDEP as the potential cause of the lesions on fish in the estuary. However, at this time *Cryptoperidiniopsis* has not been linked to the lesions in the St. Lucie Estuary or to human health effects anywhere.

Based on available literature, some aspects of the relationship between regulatory releases and ecological effects on fishing are relatively clear. In general, the St. Lucie Estuary ecosystem is stressed by magnified oscillations in freshwater inputs to the estuary and other ecosystem perturbations. The stressors include Lake Okeechobee releases and other influences from the estuary's watershed. The variability in freshwater inputs to the estuary creates an unstable salinity environment (Chamberlain and Hayward, 1996). The turbidity and sedimentation impacts on seagrass communities may be the principal long-term concern regarding freshwater inputs to the estuary (Haunert and Startzman, 1985). However, there are also concerns about the effects of low-flow periods, particularly with regard to dissolved oxygen levels. While in some instances the effects of releases may be difficult to distinguish from watershed effects, it appears that regulatory releases do affect commercial and recreational fisheries in the estuary (Haunert and Startzman, 1980; Van Os et al., 1980).

Unfortunately, there is a great deal of uncertainty regarding the effects of the freshwater releases from Lake Okeechobee on the St. Lucie Estuary. Estuarine ecosystems are complex, and the linkages between causes (e.g., ecosystem perturbations) and effects (e.g., changes in the structure or function of the ecosystem) are often unclear. There are multiple research topics that need to be explored to fully understand these linkages. These topics include distinguishing between: (1) the impacts of regulatory releases and runoff from the watershed, (2) short-term and long-term effects of the releases, (3) the few high level releases and the more numerous smaller events, and (4) low and high flow violations of the desired salinity targets.

Ecological uncertainties compound the economic uncertainties regarding commercial and recreational fishing. An example of the relationship between uncertainties in ecological and economic response to the regulatory releases is provided by the regulatory releases which occurred during the spring of 1998. During 1998 spring releases, gamefish disappeared due to the salinity effects, and the commercial and recreational fishery was severely impacted. However, by June of 1998, gamefish had returned to the estuary and guided sportfishing and recreational fishing had rebounded.

The economic effects would seem to be clearly bounded by the effects on fishing, since adult gamefish relocate during release periods (Van Os et al., 1980). However, the loss of juveniles and loss of habitat due to sedimentation effects on seagrass may not affect fishing and the economics of fishing for years to come. In addition, for those offshore commercial species that reside in estuarine waters during their larval or juvenile stages, the economic effects of changes in the estuarine ecology could be manifested in offshore commercial or recreational landings or in the landings of another county.

The challenge in determining the economic impacts on commercial and recreational fishing in the St. Lucie Estuary is further complicated by the need to differentiate between the with- and without-project future conditions in order to isolate the effects of the alternative regulation schedules. Given these considerations, the determination of an actual dollar estimate of the effects of the alternative plans on commercial and recreational fishing is beyond the limits of this investigation. However, the hydrologic effects of the alternative plans simulated in the SWFMM can be interpreted from the perspective of the fishing industry by combining the profile of commercial and recreational fishing with the current understanding of the ecological effects of regulatory releases on the estuary.

As indicated in Table 7-5, the alternative regulation schedules are all expected to result in improvements over the without-project future condition. However, they are not expected to meet the performance targets. The relative performances of the alternative regulation schedules allow the plans to be compared, but the monetary estimation of the economic effects on the commercial and recreational fishery will require additional research into the ecology and economics of the estuary.

The SFWMD is currently attempting to fill some of the information gaps that exist in the hydrology-ecology-economics chain of cause-and-effect as regards freshwater releases from Lake Okeechobee. In June 1998, the SFWMD sponsored a series of focus groups in Martin and St. Lucie counties that are intended to assemble local businesses affected by the large regulatory releases to the St. Lucie Estuary in the spring of 1998 and to identify the economic impacts on these businesses and the regional economy.

## 7.5 POTENTIAL EFFECTS ON FISHING IN CALOOSAHATCHEE ESTUARY

While the issues regarding Lake Okeechobee releases to the Caloosahatchee Estuary are similar to the St. Lucie Estuary, there are several important differences as well. Similarities include: (1) the purposes and timing of the regulatory and non-regulatory releases from Lake Okeechobee and (2) the uncertainties in the causal relationship between hydrologic changes in the releases, the consequent ecological effects, and the economic impacts on commercial and recreational fishing. Differences include: (1) the larger size of the Caloosahatchee Estuary relative to the St. Lucie Estuary, (2) the larger releases from the lake down this waterway, and (3) the ecological distinctions between the Caloosahatchee and St. Lucie estuaries.

As part of this investigation, a variety of individuals, organizations, and institutions were contacted to identify pertinent studies and individuals with expertise regarding the impacts of the freshwater releases from Lake Okeechobee on the Caloosahatchee Estuary. Contacts included:

- Harbor Branch Oceanographic Institute,
- Caloosahatchee River Citizens Committee,
- Lee County Professional Guides Association,
- Florida Marine Research Institute,
- Florida Sea Grant,
- Florida Bureau of Seafood and Aquaculture,
- Florida Center for Environmental Studies, Tarpon Bay Research Center,
- City of Sanibel,
- Lee County,
- Gulf of Mexico Program,
- Gulf of Mexico Foundation,
- Charlotte Harbor National Estuary Program,
- Southwest Florida Regional Planning Council, and
- SFWMD.

In 1995, Charlotte Harbor, which adjoins the Caloosahatchee Estuary, was included in the National Estuary Program (NEP). The Charlotte Harbor NEP effort included two studies with direct relevance for this investigation. The first is a review of the physical setting in the Caloosahatchee Estuary. The second is an estimate of the economic value of resources in the Charlotte Harbor study area, which includes the Caloosahatchee River.

Goodwin (1996) modeled the currents in the area of San Carlos Bay and concluded that much of the regulatory discharges from the Caloosahatchee River pass southward under the Sanibel Causeway and enter the Gulf of Mexico. However, under certain conditions, some of this freshwater can be transported into Pine Island Sound and Matlacha Pass. The extent of the effects of regulatory releases from the lake are variable, depending on the release rate and the wind and tidal conditions in the estuary. Based on discussions with some of the previously listed organizations, the effects of large freshwater releases, such as those experienced in the spring of 1998, extend into San Carlos Bay, Matlacha Pass, Pine Island Sound, and Estero Bay. According to local residents, the tanin-colored waters from Lake Okeechobee are quite apparent as they darken the waters of San Carlos Bay.

It appears that the sedimentation effects of the releases on the Caloosahatchee Estuary are less problematic than the nutrient effects of the releases, relative to the St. Lucie Estuary. Red tides (i.e., marine algae blooms) were consistently described during interviews as a more significant ecological and economic threat than freshwater releases from Lake Okeechobee. Red tides kill fish, ruin fishing, and close beaches with the stench of dead fish and the effects of algae on bathers' respiratory systems (e.g., throat and sinus irritation). The two issues may be interconnected, since algae blooms have been linked to nutrient inputs to coastal waters. However, there are significant sources of nutrients in these coastal waters other than water released from the lake. Phosphate mining, agriculture, and wastewater discharges contribute to the nutrient levels in the coastal waters of Lee County.

### 7.5.1 Profile of Commercial and Recreational Fisheries

As in the case of the St. Lucie Estuary, a profile of commercial and recreational fishing in the Caloosahatchee Estuary can be constructed using field information and data in national and state fishing databases. Again, much of the available information about commercial and recreational fishing in the estuary is contained in studies and data sets for larger geographic areas.

There is some commercial fishing in the Caloosahatchee Estuary. The use of cast nets in the estuary is reported to be common. In addition, there is reported to be substantial crabbing activity in the estuary. In Lee County, there are 638 saltwater products licenses and 267 permits for blue crab fishing.

The Caloosahatchee Estuary has important ecological connections with offshore commercial fish stocks. As described in Nelson (1992), many commercial finfish and invertebrate species use estuaries for critical stages of their development. Table 7-6 presents commercial landings, trips, and value data collected by the Florida DEP for the Pine Island Sound/San Carlos Bay area. As indicated in this table, in 1997 the value of the commercial landings from this area were approximately $1.7 million. The finfish and bait shrimp fisheries account for most of the landings and value. Although the shrimp landings in Table 7-6 are small, there is a significant offshore pink shrimp fishery that is based on Sanibel Island. This fishery is reflected in 1997 pink shrimp landings data for Lee County, which totaled 4,033,537 pounds. The Caloosahatchee Estuary and the area affected by freshwater releases from Lake Okeechobee comprise part of the nursery habitat for this fishery. The finfish and bait shrimp poundage, trips, and value data vary widely from year to year. This is due to changes in the fish population dynamics, fishing conditions, and fishing effort.

**TABLE 7-6**
**COMMERCIAL LANDINGS**
**PINE ISLAND SOUND/SAN CARLOS BAY**
**1993-1997**

| | | 1993 | 1994 | 1995 | 1996 | 1997 |
|---|---|---|---|---|---|---|
| Finfish | Pounds | 1,084,476 | 174,582 | 260,175 | 479,160 | 1,036,342 |
| | Trips | 4,853 | 783 | 1,682 | 2,745 | 3,881 |
| | Value | $629,297 | $134,862 | $274,862 | $492,314 | $867,150 |
| Invertebrates | Pounds | 1,484 | 1,864 | 32,583 | 410,203 | 196,409 |
| | Trips | 11 | 13 | 111 | 1,391 | 1,373 |
| | Value | $1,435 | $1,299 | $31,560 | $219,301 | $247,464 |
| Shrimp | Pounds | 2,017 | 0 | 0 | 0 | 0 |
| | Trips | 9 | 0 | 0 | 0 | 0 |
| | Value | $6,250 | $0 | $0 | $0 | $0 |
| Bait Shrimp | Pounds | 89,165 | 114,982 | 118,009 | 136,356 | 147,564 |
| | Trips | 1,762 | 1,961 | 2,105 | 2,735 | 2,749 |
| | Value | $213,630 | $265,397 | $369,182 | $513,383 | $556,705 |

Source: Florida DEP, 1997

The data in Table 7-6 are complemented by the information in Table 7-7 and Table 7-8. Table 7-7 contains 1997 landings data from nearby Charlotte Harbor (to the north) and Estero Bay (to the south). As indicated in Table 7-7, the finfish fishery in Charlotte Harbor is substantially larger than that of the Pine Island/San Carlos Bay area.

Table 7-8 contains ranked landings of the top nine commercial species in Lee County, by weight. Each of these nine species account for at least one percent of the total county catch by weight (2,599,308 pounds). Together, they account for 95% of the total catch. Most of these species reside in estuarine habitat for at least part of their life stage. The 1997 commercial invertebrate landings for Lee County include: blue crabs (1,409,015 pounds) and stone crabs (151,330 pounds). In addition, the 1997 shrimp landings for Lee County were 4,224,879 pounds.

**TABLE 7-7**
**COMMERCIAL LANDINGS**
**CHARLOTTE HARBOR; ESTERO BAY**
**1997**

| AREA | CATEGORY | POUNDS | TRIPS | VALUE |
|---|---|---|---|---|
| Charlotte Harbor | Finfish | 1,787,612 | 6,103 | $1,293,085 |
| | Invertebrates | 748,850 | 4,446 | $701,355 |
| | Shrimp | 14,609 | 141 | $40,562 |
| | Bait Shrimp | 0 | 0 | $0 |
| Estero Bay | Finfish | 100,947 | 428 | $70,768 |
| | Invertebrates | 2,766 | 25 | $11,236 |
| | Shrimp | 0 | 0 | $0 |
| | Bait Shrimp | 0 | 0 | $0 |

Source: Florida DEP, 1997.

**TABLE 7-8**
**RANKED COMMERCIAL FINFISH LANDINGS BY WEIGHT**
**LEE COUNTY**
**1997**

| SPECIES | POUNDS | PERCENT OF TOTAL CATCH |
|---|---|---|
| Mullet, Black | 1,714,122 | 66% |
| Grouper, Red | 270,762 | 10% |
| Pompano | 134,932 | 5% |
| Mojarra | 80,428 | 3% |
| Jack, Mixed | 71,064 | 3% |
| Grouper, Gag | 39,989 | 2% |
| Jack, Crevalle | 33,991 | 1% |
| Ladyfish | 30,758 | 1% |
| Grouper, Black | 22,737 | 1% |

Source: Florida Marine Fisheries Information System

The Caloosahatchee Estuary also supports guided sportfishing and recreational fisheries. Nelson (1992) described the following recreational species as "highly abundant", "abundant", or "common" in the Caloosahatchee Estuary: tarpon, sea catfish, snook, crevalle jack, silver perch, pinfish, spotted seatrout, red drum, black drum, and stripped mullet.

According to interviews with the Lee County Professional Guides Association, there are approximately 60 guides who operate in Lee County, mostly on a full-time basis. Many of the guides fish in the Caloosahatchee River at least some of the time. An even larger number of guides fish in the area that is potentially subject to the effects of the lake releases. It appears that guides will frequently take charters into the Caloosahatchee River to fish for tarpon or to escape windy conditions on the coast. Guides in the area typically pursue tarpon, spotted seatrout, snook, and red drum. Assuming that the guides charge an average of $350 per day, guided sportfishing in the area would have an approximate annual value of $4.8 million. The guides indicate that while the majority of their charters consist of tourists, there are also significant numbers of charters by Florida residents. The ratio of resident/tourist charters of 40/60 was considered representative for much of the year, changing to 20/80 during the tourist season.

Recreational fishing in the Caloosahatchee Estuary is also popular with local anglers. Bell et al. (1982) estimated that the overall economic value of recreational fisheries to a region can be as much as six times that of commercial fisheries. Unfortunately, no current participation rates for recreational fishing in the estuary were identified as part of this investigation. However, a representative picture of recreational fishing in the Caloosahatchee Estuary can be constructed using studies of recreational fishing that include the estuary.

1. The 1996 National Survey of Recreational Fishing conducted by the NOAA for the west coast of Florida are presented in Table 7-9 for those species which account for at least one percent of the catch. Many of those species spend much of their lives in estuarine waters.

2. Bell et al. (1982) estimated that 61.5% of recreational fishing trips are within brackish coastal waters or within 3 miles of shore, where fish stocks are largely dependent on estuaries

3. The state-wide survey of resident anglers by Milon and Thunberg (1993) estimated that for the Florida Marine Fisheries Commission Region 3, which includes the Caloosahatchee Estuary, over 65% of the total fishing effort was expended in near-shore waters or within the estuary or lagoon complex. Their findings suggest that 88% of the recreational fishing by Florida residents in the lagoon is done by people who reside in the region. In addition, their surveys indicate that sea trout, snook, and red drum are the most popular species with anglers, pursued by 48% of the anglers who expressed species preference.

4. Bell's (1993) study of fishing by Florida tourists estimated that 16.5% of tourists visiting Florida engaged in saltwater fishing in the last year. However, 90% of the tourist anglers do not come primarily to fish, and two-thirds of these anglers have no target species.

**TABLE 7-9**
**RECREATIONAL LANDINGS**
**WEST COAST OF FLORIDA**
**1996**

| SPECIES | LANDINGS | PERCENT |
|---|---|---|
| Seatrout, spotted | 2,762,297 | 11% |
| Pinfishes | 2,486,234 | 10% |
| Sheepshead | 896,605 | 3% |
| Saltwater catfishes | 866,782 | 3% |
| Snapper, gray | 818,934 | 3% |
| Drum, red | 732,176 | 3% |
| Jack, crevalle | 663,931 | 3% |
| Mullets | 278,833 | 1% |
| Groupers | 263,856 | 1% |
| Perch, silver | 236,575 | 1% |
| Grunt, white | 221,545 | 1% |
| Pigfish | 194,270 | 1% |
| Seatrout, sand | 183,686 | 1% |

Source: NOAA. National Survey of Recreational Marine Fishing. 1996.

Lee County is also home to an emerging aquaculture industry. Since the State of Florida instituted the gill net ban in 1994, it has encouraged aquaculture to mitigate the economic effects on watermen and coastal communities and to meet the growing demand for seafood. In Lee County, there are over 10 aquaculture farms, which primarily raise hard clams. The Harbor Branch Oceanographic Institute has received a state grant to provide technical support for clam aquaculture. Some of these operations raise seed clams for sale to other aquaculture farmers; others raise mature clams for commercial sale. The seed clam operations typically use a closed (recycling) water system. The clam farms which are raising mature clams in Lee County are located in Pine Island Sound near the midpoint of Pine Island. It is anticipated that the releases from Lake Okeechobee will not have a significant effect on aquaculture operations in Lee County for two reasons: (1) the seed clams, which are potentially vulnerable to sudden and drastic salinity changes, are not exposed to the freshwater releases from the Caloosahatchee

River and (2) the clam farms that raise clams to maturity are sufficiently removed from the more extreme effects of the freshwater releases.

### 7.5.2 Hydrologic Changes Associated With Alternative Regulation Schedules

The SFWMM-simulated hydrologic effects of the alternative regulation schedules on the Caloosahatchee Estuary are presented in Table 7-10. Regarding the first measure in this table (number of months with mean flow greater than 2800 cfs), the alternative regulation schedules are expected to have equivalent performance to the 1990 and 2010 without-project conditions. The exception is the WSE schedule which is expected to exceed the performance of Run25 and the other alternative schedules. However, the with- and without-project 1990 and 2010 conditions are not expected to meet the targets for this measure. The second measure in this table indicates the expected number of months in the first measure that are attributable to Lake Okeechobee releases. The SFWMM differentiates the inflows from the estuary's watershed from Lake Okeechobee releases. As indicated in the results of the second measure, the Lake Okeechobee releases account for a relatively small percentage of the total number of times that the flow target is exceeded in the SFWMM scenarios. The alternative regulation schedules are expected to meet or exceed the performance of Run25, with the exception of the WSE schedule. The third measure (number of months with mean flow greater than 4500 cfs) has results that are similar to the first measure. The alternative schedules are expected to exceed the performance of the without-project 1990 and 2010 conditions, but they are not anticipated to meet the performance targets.

**TABLE 7-10**
**SIMULATED HYDROLOGIC PERFORMANCE OF ALTERNATIVE PLANS**
**CALOOSAHATCHEE ESTUARY**

| PERFORMANCE MEASURE | Scenario | Run25 | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|---|---|
| Number of months mean flow > 2800 cfs (target: 22) | 1990 | 47 | 47 | 47 | 47 | 46 |
| | 2010 | 44 | 44 | 44 | 44 | 44 |
| Number of months mean flow > 2800 cfs due to lake releases* | 1990 | 27 | 25 | 22 | 24 | 34 |
| | 2010 | 19 | 12 | 14 | 19 | 28 |
| Number of months mean flow > 4500 cfs (target: 6) | 1990 | 36 | 30 | 32 | 31 | 31 |
| | 2010 | 28 | 25 | 25 | 25 | 27 |

* mean flows are attributable to lake releases and Caloosahatchee basin drainage

### 7.5.3 Potential Ecological and Economic Effects of Hydrologic Changes

Based on available literature, some aspects of the relationship between the regulatory releases and effects on fishing are relatively clear. In general, the Caloosahatchee Estuary ecosystem is stressed by the magnified oscillations in freshwater inputs to the estuary and other ecosystem perturbations. The stressors include the Lake Okeechobee releases and other influences from the estuary's contributing watershed. As in the St. Lucie Estuary, the variability in freshwater inputs to the Caloosahatchee Estuary creates an unstable salinity environment. The work of Doering and Chamberlain (1997) suggests that turbidity and dissolved oxygen levels are comparable to other Florida estuaries, but nitrogen concentrations are relatively high. They also note that, in general, water quality deteriorates with distance upstream from the mouth of the estuary. While in some instances the effects of the releases may be difficult to distinguish from effects of the Caloosahatchee River's relatively large watershed, it appears that the regulatory releases affect the commercial and recreational fisheries in the estuary.

Unfortunately, as in the case of the St. Lucie Estuary, there is a great deal of uncertainty regarding the effects of the freshwater releases from Lake Okeechobee on the Caloosahatchee Estuary. Estuarine ecosystems are complex, and the linkages between causes (e.g., ecosystem perturbations) and effects (e.g., changes in the structure or function of the ecosystem) are often unclear. There are multiple research topics that need to be explored to fully understand these linkages. These topics include distinguishing between the effects of: (1) the impacts of lake releases and freshwater inflow from the watershed, (2) short-term and long-term effects of the releases, (3) the few high level releases and the more numerous smaller events, and (4) low and high flow violations of the desired salinity envelope.

The ecological uncertainties compound the economic uncertainties regarding commercial and recreational fishing. As in the St. Lucie Estuary, the return of gamefish following a period of large releases to the estuary may not fully reflect the impacts on the fisheries. The economic effects would seem to be clearly bounded by the effects on fishing, since adult gamefish relocate during release periods (Van Os et al., 1980). However, the loss of juveniles and loss of habitat due to impacts on seagrass communities may not affect fishing and the economics of fishing for years to come.

The challenge in estimating the economic effects on commercial and recreational fishing in the Caloosahatchee Estuary is further complicated by the need to differentiate between the with- and without-project future conditions in order to isolate the effects of the alternative regulation schedules. Given these considerations, the determination of a dollar value of the effects of the alternative plans is beyond the scope of this investigation. However, the simulated hydrologic effects of the alternative plans can be interpreted from the perspective of the economics of commercial fishing by combining the profile of commercial and recreational fishing with current understanding of the ecological effects of regulatory releases on the estuary.

As indicated in Table 7-10, the alternative regulation schedules are expected to result in improvements over the without-project future condition with respect to low and high water inputs to the Caloosahatchee Estuary. However, they are not expected to meet the performance targets. The relative performances of the alternative regulation schedules allow the plans to be ranked, but the monetary estimation of the economic effects on the commercial and recreational fishery will require additional research into the ecology and economics of the estuary.

## 7.6 SUMMARY OF POTENTIAL ECONOMIC EFFECTS ON FISHING

The potential effects of the LORSS alternative regulation schedules are summarized in Table 7-11. This table presents estimates of current annual revenues for each of the fisheries under consideration. As described in the above discussions, these estimates were generated using a variety of approaches and data sources. Consequently, the estimates should be considered approximate, and comparisons of the revenues of one fishery with another should be made with caution. Table 7-11 also contains information on the anticipated hydrologic performance of the alternative regulation schedules. In general, the alternative plans are expected to comprise improvements over the without-project future conditions. The economic interpretation of this hydrologic information suggests that the alternative plans could result in improvements in the economics of commercial and recreational fishing relative to the existing and without-project future conditions. The quantification of the expected economic impacts is not possible at this time given knowledge and data gaps in the sequence of hydrologic, ecological, and economic effects that determine economic impacts of the alternative regulation schedules.

## TABLE 7-11
## SUMMARY OF ECONOMIC EFFECTS OF ALTERNATIVE PLANS ON ESTUARINE FISHERIES

| Area | Approximate Annual Revenues of Fishery ($ million) | | | Hydrologic Performance Of Alternative Schedules | | Economic Interpretation of Hydrologic Performance |
|---|---|---|---|---|---|---|
| | Commercial | Guided | Recreational | Performance Relative to Without-Project Conditions | Performance Relative to Targets | |
| St. Lucie Estuary | $1.7 | $0.8 | n.a. | Alternatives meet or exceed Run25 performance | Alternatives do not meet targets | Positive economic impacts expected with alternative regulation schedules |
| Caloosahatchee Estuary | $1.7 | $4.8 | n.a. | Alternatives meet or exceed Run25 performance | Alternatives do not meet targets | Positive economic impacts expected with alternative regulation schedules |

# 8. REGIONAL ECONOMIC IMPACTS

## OVERVIEW

This chapter examines the potential effects of the alternative regulation schedules on the Regional Economic Development (RED) account. The RED account registers indirect and secondary effects to the region that are expected to result from the direct economic effects of the alternative plans. Direct economic effects represent the impacts of economic stimuli in terms of changes in regional industrial output, earnings, or employment. Indirect economic impacts represent the resultant economic changes in the industries that support and rely upon the industries directly affected by the stimuli. In addition, induced economic impacts are those impacts experienced by all local industries as direct and indirect effects alter household income and ultimately change local household spending patterns.

## 8.1 METHODOLOGY

A regional input-output model, *IMPLAN*[1], was used to estimate the RED effects of the LORSS alternative regulation schedules. Regional input-output (I-O) analysis provides the classic tool for tracing economic ripples through the economy. Based on the region's industrial structure, I-O analysis tracks the expected inter-industry flow of goods and services. For the RED analysis, the regional economy was defined as encompassing 13 Florida counties (Broward, Charlotte, Collier, Dade, Glades, Hendry, Highlands, Lee, Martin, Monroe, Okeechobee, Palm, Beach, and St. Lucie) using *IMPLAN*. Using county-level economic data, which was procured from the software vendor, the model was used to estimate the economic effects of the alternative regulation schedules on wages, employment, and industrial output. Specifically, IMPLAN was employed in a four-part methodology to: (1) describe the study area economy, (2) create economic scenarios, (3) introduce economic changes, and (4) estimate resulting direct, indirect, and induced economic effects.

Economic scenarios were created in *IMPLAN* to characterize the future conditions in each industry under each regulation alternative. Not all of the potential direct effects can be evaluated in the RED analysis. For example, it was not possible to evaluate the M&I water supply effects of the alternative plans in the RED account. The M&I water supply effects associated with the alternative regulation schedules were developed using willingness-to-pay estimates for water supplies that would be unavailable during water shortages. Industrial water users may experience monetary income losses associated with water use cutbacks during shortages, but these effects cannot be distinguished from the combined willingness-to-pay values derived from a survey of industrial, commercial, and residential users. In addition, commercial and residential water users primarily experience non-monetary effects from water shortages, representing their loss of satisfaction, rather than a reduction in household income.

[1] MIG, Inc. Implan System (1994 data and Software) 1940 South Greely Street, Suite 101 Stillwater MN 55082

Similar willingness-to-pay issues precluded some agricultural water supply effects from inclusion in the RED account. Specifically, urban landscape and golf turf effects were calculated using willingness-to-pay estimates. Since these estimates also represent reductions in satisfaction, not reductions in income, they were excluded from the RED analysis.

In addition to M&I water supply and several agricultural water supply categories, three other NED categories (e.g., commercial navigation, recreation, and commercial fishing) were not evaluated in the RED analysis. There are two principal reasons for this exclusion. First, the alternative regulation schedules are expected to have minor economic consequences associated with commercial navigation, recreation, and commercial fishing. Second, the procedures used to estimate the NED effects on these economic categories generated illustrative scenarios, not quantitative estimates of NED effects. Consequently, interpretations of their results should be limited to comparisons of the alternative plans.

Recognizing these exclusions, the RED analysis focused on the indirect and induced effects of the agricultural water supply impacts of the alternative regulation schedules. The total agricultural water supply effects generated using the SFWMM's economic post-processor (EPP) for each service area were developed in Chapter 2 of this report. For the RED analysis, these values have been distributed into the nine agricultural sectors used by the SFWMM and its EPP: urban landscape, sod, nursery, golf turf, tomatoes, avocados, citrus, rice, and sugarcane (see Table 8-1). The agricultural effects (i.e., the value of unmet demand) presented in Table 8-1 represent changes in farm income (or industry output) associated with each alternative regulation schedule and the without-project condition (Run25).

**TABLE 8-1**
**SIMULATED 2010 AVERAGE ANNUAL VALUE OF UNMET AGRICULTURAL WATER DEMAND BY AGRICULTURAL SECTOR IN THE LEC AND EAA**

| EPP LAND USE CATEGORY | Run25 | ALTERNATIVE REGULATION SCHEDULES | | | |
|---|---|---|---|---|---|
| | | Run22AZE | COEREC | HSMREC | WSE |
| Urban landscape | $577,664 | $597,279 | $604,676 | $605,103 | $557,664 |
| Other – Sod | $0 | $0 | $0 | $0 | $0 |
| Nursery | $406,746 | $399,657 | $411,345 | $411,403 | $406,746 |
| Golf turf | $5,063,684 | $5,160,908 | $5,069,310 | $4,929,153 | $4,948,910 |
| Tomatoes (vegetables) | $31,837 | $32,428 | $32,428 | $32,428 | $31,837 |
| Citrus | $0 | $0 | $0 | $0 | $0 |
| Avocado | $0 | $0 | $0 | $0 | $0 |
| Rice | $0 | $0 | $0 | $0 | $0 |
| Sugarcane | $3,944,155 | $5,128,411 | $4,414,087 | $3,410,961 | $3,870,998 |
| Total | $10,024,086 | $11,318,683 | $10,531,847 | $9,389,048 | $9,836,156 |

The net agricultural effects (i.e., the difference between with- and without-project conditions) are presented in Table 8-2. These estimates form the basis for the RED analysis. The values in this table correspond to specific economic sectors in *IMPLAN* economic databases (fruits, vegetables, greenhouse, sugar crops and food grains). As in the EPP, tomatoes represent overhead-irrigated truck vegetables. Also, the *IMPLAN* model uses sugar cane, not raw sugar as an input. As indicated above, the values listed in Table 8-2 for the urban landscape and golf turf represent willingness to pay, not real reductions in income; and they are not included in the RED analysis. The remaining seven agricultural sectors: sod, nursery, tomatoes, citrus, avocado, rice and sugarcane were carried forward in the RED analysis.

**TABLE 8-2**
**SIMULATED NET NED EFFECTS**
**AGRICULTURAL WATER SHORTAGES**
**BY EPP CATEGORY AND *IMPLAN* SECTOR**

| EPP Land Use Category | *IMPLAN* Economic Sector | Run22AZE | COEREC | HSMREC | WSE |
|---|---|---|---|---|---|
| Urban landscape* | None | -$19,614 | -$27,011 | -$27,438 | $20,000 |
| Other Sod | Greenhouse | $0 | $0 | $0 | $0 |
| Nursery | Greenhouse | $7,089 | -$4,600 | -$4,658 | $0 |
| Golf turf* | None | -$97,224 | -$5,626 | $134,531 | $114,774 |
| Tomatoes (vegetables) | Vegetables | -$591 | -$591 | -$591 | $0 |
| Citrus | Fruits | $0 | $0 | $0 | $0 |
| Avocado | Fruits | $0 | $0 | $0 | $0 |
| Rice | Food Grains | $0 | $0 | $0 | |
| Sugarcane | Sugar Crops | -$1,184,256 | -$469,933 | $533,194 | $73,157 |
| | Total | -$1,294,597 | -$507,761 | $635,038 | $187,931 |

* Represents willingness to pay and/or dissatisfaction, not real income reductions. Values excluded from input-output analysis

The values listed in Table 8-2 were used as inputs to the I-O model scenarios to generate direct, indirect, and induced economic impacts. All input values listed in Table 8-2 are in 1996 dollars. Prior to the analysis, the *IMPLAN* software was used to deflate input data to 1994 dollars (most current year of *IMPLAN* databases). When the analysis was complete, all model results – with the exception of employment – were re-inflated to 1996 dollars.

## 8.2 RESULTS

In Tables 8-3, 8-4, 8-5, and 8-6, the direct economic effects and aggregated indirect and induced economic effects are presented for the RUN22AZE, COEREC, HSMREC, and WSE schedules, respectively. The top portions of these tables contain the direct effects of the alternative plans to seven agricultural sectors, commercial navigation, recreation, and commercial fishing. The combined induced and indirect effects, summarized in the lower portions of these tables represent the RED effects for all other industries affected by changes in the agricultural, commercial navigation, recreation and commercial fishing industries. Again, RED effects resulting from reductions in M&I water use and the agricultural uses of urban landscape and golf turf have not been estimated. Economic impacts to total industry output and employee compensation are expected to persist through each project year, while employment effects represent the total job loss or gain over the entire project period. Wages include salaries, non-wage compensation, and benefits. Employment is measured as the number of jobs, not necessarily full-time equivalents.

As indicated in Tables 8-3, 8-4, 8-5, and 8-6, the RED analyses of the four alternative regulation schedules focus on their estimated effects on the sugar industry, specifically yields of sugarcane agriculture. While the *IMPLAN* input/output software does not explicitly describe the linkages between direct and indirect or induced effects, presumably the consequent impacts of the reduced sugarcane production on sugar mills and other sugar-related activities are registered in the following regional economic sectors: Sugar Crops, Food and Manufacturing, and Transportation and Communication.

The RUN22AZE alternative results in the largest impact to the agricultural industry (see Table 8-3). For the LEC and EAA, the annual direct effects to industry output are approximately $1.2 million, with an annual loss of $85,000 expected in employee compensation. The estimated indirect and induced effects include annual losses of $631,000 in industry output and an annual reduction in employee compensation of $201,000 across all economic sectors.

Economic impacts resulting from implementation of the COEREC are more favorable (see Table 8-4). Direct effects in the LEC and EAA include annual reductions in industry output of approximately $475,000 with additional annual losses of $36,000 in farm employee compensation. Induced and indirect effects include annual losses of approximately $257,000 in total industry output, as well as $82,000 in employee compensation.

Alternative HSMREC is expected to have an overall positive impact on the local economy (see Table 8-5). While the LEC service areas expect small annual losses in the greenhouse and fruit sectors, the combined direct effect on industry output is estimated to be an increase of $527,000 annually and the combined direct effect on annual employee compensation to be $38,000. The resulting induced and indirect effects on total industry output are also expected to be positive, increasing annual industry output by $485,000 annually and annual employee compensation by $90,000.

The final alternative, WSE, is also expected to have an overall positive impact on the local economy (see Table 8-6). This alternative is expected to result in direct increases to industry output of $281,000 and to employee compensation of $14,000. The resulting induced and indirect effects are also expected to be positive, increasing annual regional industry output by $150,000 and annual regional employee compensation by $47,000.

Regional statistics (MIG,1994) indicate that the annual total industry output, employee compensation and employment in the study area are $231.2 billion annually, $77.5 billion annually, and 2.9 million, respectively in 1996 dollars. The percentage of region total values listed in Tables 8-3, 8-4, 8-5, and 8-6 show that across the study region, all estimated economic impacts are negligible when compared to the region as a whole.

## TABLE 8-3
## ESTIMATED RED EFFECTS
## RUN22AZE

| IMPLAN Economic Sector | Annual Industry Output ($1996) | Annual Employee Compensation ($1996) | Employment (# jobs) |
|---|---|---|---|
| **Run22AZE Direct Effects** | | | |
| Sugar Crops | -$1,184,256 | -$86,749 | -17 |
| Greenhouse and Nursery Products | $7,089 | $1,506 | 0 |
| Vegetables | -$591 | -$44 | 0 |
| Fruits | $0 | $0 | 0 |
| Food Grains | $0 | $0 | 0 |
| **Run22AZE Direct Effects** | **-$1,177,758** | **-$85,288** | **-17** |
| **% of Region Total** | **-0.0000051%** | **-0.0000011%** | **-0.0000058%** |
| **Run22AZE Indirect & Induced Effects** | | | |
| Sugar Crops | -$13,965 | -$1,023 | 0 |
| Greenhouse and Nursery Products | -$591 | -$126 | 0 |
| Fruits | -$793 | -$85 | 0 |
| Other Ag. Production & Services | -$25,375 | -$11,963 | -1 |
| Stone Mining and Natural Gas | -$174 | -$27 | 0 |
| Construction | -$14,445 | -$4,370 | 0 |
| Food & Manufacturing | -$5,053 | -$866 | 0 |
| Other Manufacturing | -$22,467 | -$5,712 | 0 |
| Transportation & Communication | -$33,587 | -$6,867 | 0 |
| Utilities | -$20,392 | -$3,703 | 0 |
| Wholesale and Retail Trade | -$135,264 | -$57,485 | -3 |
| Financial, Insurance, & Real Estate | -$164,587 | -$21,299 | -1 |
| Personal Services | -$15,932 | -$5,230 | 0 |
| Professional Services & Business Products | -$45,044 | -$16,949 | -1 |
| Entertainment | -$12,794 | -$4,071 | 0 |
| Health & Social Services | -$85,985 | -$44,032 | -1 |
| Legal & Educational Services | -$19,857 | -$11,252 | 0 |
| State & Local Government | -$9,878 | -$2,218 | 0 |
| Federal Government | -$3,738 | -$2,675 | 0 |
| Miscellaneous | -$1,426 | -$1,426 | 0 |
| **Run22AZE Indirect & Induced Effects** | **-$631,348** | **-$201,377** | **-9** |
| **% of Region Total** | **-0.0000027%** | **-0.0000026%** | **-0.0000030%** |

# TABLE 8-4
# ESTIMATED RED EFFECTS
# COEREC

| IMPLAN Economic Sector | Annual Industry Output ($1996) | Annual Employee Compensation ($1996) | Employment (# jobs) |
|---|---|---|---|
| **COEREC Direct Effects** | | | |
| Sugar Crops | -$469,933 | -$34,423 | -7 |
| Greenhouse and Nursery Products | -$4,600 | -$977 | 0 |
| Vegetables | -$591 | -$44 | 0 |
| Fruits | $0 | $0 | 0 |
| Food Grains | $0 | $0 | 0 |
| **COEREC Direct Effects** | **-$475,124** | **-$35,445** | **-7** |
| **% of Region Total** | **-0.0000021%** | **-0.0000005%** | **-0.0000024%** |
| **COEREC Indirect & Induced Effects** | | | |
| Sugar Crops | -$5,543 | -$406 | 0 |
| Greenhouse and Nursery Products | -$566 | -$120 | 0 |
| Fruits | -$324 | -$35 | 0 |
| Other Ag. Production & Services | -$10,409 | -$4,910 | -1 |
| Stone Mining and Natural Gas | -$71 | -$11 | 0 |
| Construction | -$5,872 | -$1,777 | 0 |
| Food & Manufacturing | -$2,048 | -$351 | 0 |
| Other Manufacturing | -$9,111 | -$2,317 | 0 |
| Transportation & Communication | -$13,720 | -$2,805 | 0 |
| Utilities | -$8,343 | -$1,513 | 0 |
| Wholesale and Retail Trade | -$55,018 | -$23,372 | -1 |
| Financial, Insurance, & Real Estate | -$66,590 | -$8,623 | 0 |
| Personal Services | -$6,466 | -$2,123 | 0 |
| Professional Services. & Business Products | -$18,284 | -$6,880 | 0 |
| Entertainment | -$5,188 | -$1,651 | 0 |
| Health & Social Services | -$34,850 | -$17,846 | -1 |
| Legal & Educational Services | -$8,053 | -$4,563 | 0 |
| State & Local Government | -$4,010 | -$900 | 0 |
| Federal Government | -$1,517 | -$1,085 | 0 |
| Miscellaneous | -$578 | -$578 | 0 |
| **COEREC Indirect & Induced Effects** | **-$256,559** | **-$81,865** | **-4** |
| **% of Region Total** | **-0.0000011%** | **-0.0000011%** | **-0.0000012%** |

# TABLE 8-5
# ESTIMATED RED EFFECTS
# HSMREC

| IMPLAN Economic Sector | Annual Industry Output ($1996) | Annual Employee Compensation ($1996) | Employment (# jobs) |
|---|---|---|---|
| **HSMREC Direct Effects** | | | |
| Sugar Crops | $533,194 | $39,057 | 8 |
| Greenhouse and Nursery Products | -$4,658 | -$989 | 0 |
| Vegetables | -$591 | -$44 | 0 |
| Fruits | $0 | $0 | 0 |
| Food Grains | $0 | $0 | 0 |
| **HSMREC Direct Effects** | **$527,945** | **$38,024** | **8** |
| **% of Region Total** | **0.0000023%** | **0.0000005%** | **0.0000026%** |
| **HSMREC Indirect & Induced Effects** | | | |
| Sugar Crops | $6,287 | $461 | 0 |
| Greenhouse and Nursery Products | $198 | $42 | 0 |
| Fruits | $354 | $38 | 0 |
| Other Ag. Production & Services | $11,306 | $5,330 | 1 |
| Stone Mining and Natural Gas | $78 | $12 | 0 |
| Construction | $6,466 | $1,956 | 0 |
| Food & Manufacturing | $2,263 | $388 | 0 |
| Other Manufacturing | $10,059 | $2,557 | 0 |
| Transportation & Communication | $15,020 | $3,071 | 0 |
| Utilities | $9,118 | $1,656 | 0 |
| Wholesale and Retail Trade | $60,539 | $25,730 | 1 |
| Financial, Insurance, & Real Estate | $73,741 | $9,542 | 0 |
| Personal Services | $7,133 | $2,342 | 0 |
| Professional Services & Business Products | $20,168 | $7,588 | 0 |
| Entertainment | $5,729 | $1,823 | 0 |
| Health & Social Services | $38,508 | $19,719 | 1 |
| Legal & Educational Services | $8,892 | $5,038 | 0 |
| State & Local Government | $4,423 | $993 | 0 |
| Federal Government | $1,674 | $1,198 | 0 |
| Miscellaneous | $639 | $639 | 0 |
| **HSMREC Indirect & Induced Effects** | **$282,596** | **$90,122** | **4** |
| **% of Region Total** | **0.0000012%** | **0.0000012%** | **0.0000014%** |

# TABLE 8-6
# ESTIMATED RED EFFECTS
# WSE

| IMPLAN Economic Sector | Annual Industry Output ($1996) | Annual Employee Compensation ($1996) | Employment (# jobs) |
|---|---|---|---|
| **WSE Direct Effects** | | | |
| Sugar Crops | $187,931 | $13,766 | 3 |
| Greenhouse and Nursery Products | $0 | $0 | 0 |
| Vegetables | $0 | $0 | 0 |
| Fruits | $0 | $0 | 0 |
| Food Grains | $73,157 | $562 | 2 |
| **WSE Direct Effects** | **$261,088** | **$14,328** | **4** |
| **% of Region Total** | **0.0000011%** | **0.0000002%** | **0.0000015%** |
| **WSE Indirect & Induced Effects** | | | |
| Sugar Crops | $2,223 | $163 | 0 |
| Greenhouse and Nursery Products | $210 | $45 | 0 |
| Fruits | $190 | $20 | 0 |
| Other Ag. Production & Services | $6,754 | $3,147 | 0 |
| Stone Mining and Natural Gas | $53 | $9 | 0 |
| Construction | $3,937 | $1,191 | 0 |
| Food & Manufacturing | $1,083 | $186 | 0 |
| Other Manufacturing | $5,330 | $1,345 | 0 |
| Transportation & Communication | $8,660 | $1,773 | 0 |
| Utilities | $4,795 | $878 | 0 |
| Wholesale and Retail Trade | $31,461 | $13,290 | 1 |
| Financial, Insurance, & Real Estate | $42,003 | $5,249 | 0 |
| Personal Services | $3,551 | $1,168 | 0 |
| Professional Services & Business Products | $10,759 | $4,022 | 0 |
| Entertainment | $2,787 | $889 | 0 |
| Health & Social Services | $18,400 | $9,422 | 0 |
| Legal & Educational Services | $4,361 | $2,474 | 0 |
| State & Local Government | $2,229 | $501 | 0 |
| Federal Government | $841 | $602 | 0 |
| Miscellaneous | $305 | $305 | 0 |
| **WSE Indirect & Induced Effects** | **$149,931** | **$46,679** | **2** |
| **% of Region Total** | **0.0000006%** | **0.0000006%** | **0.0000007%** |

# APPENDIX A

## 1995 FREIGHT TRAFFIC, LAKE OKEECHOBEE WATERWAY

Section Included: Junction with Intracoastal Waterway, Jacksonville to Miami, FL, to Gulf of Mexico via Clewiston and channel across Lake Okeechobee, 154.6 miles; south shore levee channel from Port Mayaca to Clewiston, 36.7 miles; natural channels along northerly shore of the lake from Port Mayaca to Moore Haven Lock, 57.3 miles; Taylor Creek to Town of Okeechobee, FL., 4 miles. Controlling Depth: 12.0 feet from Gulf of Mexico to Punta Rasa, 3.8 miles; thence 10.0 feet to Tice, Florida, 20.8 miles; thence 5 feet to the Intracoastal Waterway; and 6 feet in Taylor Creek. Project Depth: 12 feet, Gulf of Mexico to Punta Rasa; thence 10 feet to Tice, Florida; thence to the Intracoastal Waterway, 8 feet via Clewiston and the channel across the lake, or 6 feet via south shore levee channel; and 6 feet in Taylor Creek to the Town of Okeechobee.

Comparative Statement of Traffic
(thousand tons)

| Year | Total | Year | Total |
|---|---|---|---|
| 1986 | 1,320 | 1991 | 718 |
| 1987 | 676 | 1992 | 753 |
| 1988 | 696 | 1993 | 832 |
| 1989 | 680 | 1994 | 662 |
| 1990 | 665 | **1995** | **430** |

Freight Traffic, 1995
(thousand tons)

| Commodity | Grand Total | Domestic | | | | |
|---|---|---|---|---|---|---|
| | | Coastwise | | Internal | | |
| | | Through | | Inbound | Through | Intra |
| | | Upbound | Downbnd | Upbound | Downbnd | Upbound |
| **Total, all commodities** | 430 | 8 | 1 | 415 | 6 | 1 |
| **Total petroleum and petroleum products** | 423 | 7 | — | 411 | 5 | — |
| **Subtotal petroleum products** | 423 | 7 | — | 411 | 5 | — |
| 2330 distillate fuel oil | 5 | 0 | — | — | 5 | — |
| 2340 residual fuel oil | 411 | — | — | 411 | — | — |
| 2640 liquid natural gas | 6 | 6 | — | — | — | — |
| **Total primary manufactured goods** | 2 | 0 | — | 2 | — | — |
| **Subtotal lime, cement and glass** | 2 | — | — | 2 | — | — |
| 5290 misc. mineral prod. | 2 | — | — | 2 | — | — |
| **Subtotal primary non-ferrous metal products** | 0 | 0 | — | — | — | — |
| 5480 fab. metal products | 0 | 0 | — | — | — | — |
| **Total food and farm products** | 3 | — | — | 2 | — | 1 |
| **Subtotal fish** | 3 | — | — | 2 | — | 1 |
| 6134 fish (not shellfish) | 1 | — | — | — | — | 1 |
| 6136 shellfish | 2 | — | — | 2 | — | — |
| **Total all manufactured equipment, machinery and products** | 3 | 1 | 1 | — | 1 | — |
| 7110 machinery (not elec) | 3 | 1 | 1 | — | 1 | — |
| 7230 ships & boats | 0 | 0 | — | — | — | — |
| **Ton-miles (x1000)** | **9,758** | **1,187** | **179** | **8,265** | **125** | **1** |

**Tons All Traffic (x1000)** **430**
**Ton-miles All Traffic (x1000)** **9,787**

# APPENDIX B

# LOCK PERFORMANCE MONITORING SYSTEM PROFILES OF LAKE OKEECHOBEE WATERWAY LOCKS 1993-1996

# LPMS Summary by Division/District

## January - December 1993 and 1994

**Moore Haven** — Main — **South Atlantic Divisior**
**Caloosahatchee** — River Mile: 78.0 — **Jacksonville Districi**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,936 | 4,767 | 50 | 119 | 81 | 50 | 31 | 5,017 | 8 |
| Downbound | 5,296 | 5,149 | 30 | 117 | 34 | 24 | 10 | 5,330 | 5 |
| Total | 10,232 | 9,916 | 80 | 236 | 115 | 74 | 41 | 10,347 | 13 |
| **1994** | | | | | | | | | |
| Upbound | 5,058 | 4,814 | 80 | 164 | 90 | 73 | 17 | 5,148 | 25 |
| Downbound | 5,210 | 4,997 | 78 | 135 | 91 | 41 | 50 | 5,301 | 5 |
| Total | 10,268 | 9,811 | 158 | 299 | 181 | 114 | 67 | 10,449 | 30 |
| Percent Change | 0% | -1% | 98% | 27% | 57% | 54% | 63% | 1% | 131% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| **1993** | Total | Rec. | Comm. | Other | Tows | All Tows (hrs) | Delayed Tows (hrs) | (hrs) |
| Upbound | 3,502 | 3,351 | 89 | 62 | 10 | 0.02 | 0.08 | 0.75 |
| Downbound | 3,604 | 3,472 | 62 | 70 | 5 | 0.01 | 0.07 | 0.33 |
| Total | 7,106 | 6,823 | 151 | 132 | 15 | 0.01 | 0.07 | 1.08 |
| **1994** | | | | | | | | |
| Upbound | 3,375 | 3,160 | 112 | 103 | 20 | 0.03 | 0.11 | 2.12 |
| Downbound | 3,368 | 3,175 | 107 | 86 | 12 | 0.01 | 0.09 | 1.10 |
| Total | 6,743 | 6,335 | 219 | 189 | 32 | 0.02 | 0.10 | 3.22 |
| Percent Change | -5% | -7% | 45% | 43% | 113% | 100% | 43% | 198% |

**W. P. Franklin** — Main — **South Atlantic Divisior**
**Caloosahatchee** — River Mile: 122.0 — **Jacksonville Districi**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 6,352 | 6,104 | 45 | 203 | 80 | 46 | 34 | 6,432 | 6 |
| Downbound | 6,632 | 6,410 | 29 | 193 | 38 | 29 | 9 | 6,670 | 6 |
| Total | 12,984 | 12,514 | 74 | 396 | 118 | 75 | 43 | 13,102 | 12 |
| **1994** | | | | | | | | | |
| Upbound | 7,695 | 7,486 | 56 | 153 | 73 | 58 | 15 | 7,768 | 27 |
| Downbound | 7,855 | 7,658 | 53 | 144 | 65 | 19 | 46 | 7,920 | 4 |
| Total | 15,550 | 15,144 | 109 | 297 | 138 | 77 | 61 | 15,688 | 31 |
| Percent Change | 20% | 21% | 47% | -25% | 17% | 3% | 42% | 20% | 158% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| **1993** | Total | Rec. | Comm. | Other | Tows | All Tows (hrs) | Delayed Tows (hrs) | (hrs) |
| Upbound | 3,496 | 3,272 | 91 | 133 | 10 | 0.04 | 0.19 | 1.92 |
| Downbound | 3,697 | 3,498 | 62 | 137 | 7 | 0.02 | 0.09 | 0.63 |
| Total | 7,193 | 6,770 | 153 | 270 | 17 | 0.03 | 0.15 | 2.55 |
| **1994** | | | | | | | | |
| Upbound | 4,035 | 3,842 | 84 | 109 | 18 | 0.04 | 0.14 | 2.50 |
| Downbound | 4,209 | 4,033 | 78 | 98 | 16 | 0.05 | 0.16 | 2.48 |
| Total | 8,244 | 7,875 | 162 | 207 | 34 | 0.05 | 0.15 | 4.98 |
| Percent Change | 15% | 16% | 6% | -23% | 100% | 67% | 0% | 95% |

# LPMS Summary by Division/District

## January - December 1993 and 1994

**Port Mayaca** | **Main** | **South Atlantic Division**
**Okeechobee** | **River Mile: 38.5** | **Jacksonville District**

| Jan - Dec | Vessels Total | Vessels Rec. | Vessels Tows | Vessels Other | Barges Total | Barges Loaded | Barges Empty | Bottoms Total | Tonnage ktons |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | | |
| Upbound | 4,742 | 3,463 | 26 | 1,253 | 38 | 33 | 5 | 4,780 | 17 |
| Downbound | 4,535 | 3,205 | 45 | 1,285 | 104 | 73 | 31 | 4,639 | 8 |
| Total | 9,277 | 6,668 | 71 | 2,538 | 142 | 106 | 36 | 9,419 | 25 |
| **1994** | | | | | | | | | |
| Upbound | 4,797 | 3,584 | 52 | 1,161 | 68 | 21 | 47 | 4,865 | 3 |
| Downbound | 4,728 | 3,415 | 57 | 1,256 | 184 | 167 | 17 | 4,912 | 23 |
| Total | 9,525 | 6,999 | 109 | 2,417 | 252 | 188 | 64 | 9,777 | 26 |
| Percent Change | 3% | 5% | 54% | -5% | 77% | 77% | 78% | 4% | 4% |

| Jan - Dec | Lockages Total | Lockages Rec. | Lockages Comm. | Lockages Other | Number Delayed Tows | Average Delay All Tows (hrs) | Average Delay Delayed Tows (hrs) | Total Delay Time Tows (hrs) |
|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | |
| Upbound | 3,409 | 2,377 | 926 | 106 | 15 | 0.07 | 0.12 | 1.80 |
| Downbound | 3,187 | 2,146 | 942 | 99 | 28 | 0.01 | 0.02 | 0.67 |
| Total | 6,596 | 4,523 | 1,868 | 205 | 43 | 0.03 | 0.06 | 2.47 |
| **1994** | | | | | | | | |
| Upbound | 3,796 | 2,706 | 1,027 | 63 | 2 | 0.01 | 0.14 | 0.28 |
| Downbound | 3,706 | 2,615 | 1,023 | 68 | 9 | 0.03 | 0.16 | 1.48 |
| Total | 7,502 | 5,321 | 2,050 | 131 | 11 | 0.02 | 0.16 | 1.76 |
| Percent Change | 14% | 18% | 10% | -36% | -74% | -33% | 167% | -29% |

**Ortona** | **Main** | **South Atlantic Division**
**Okeechobee** | **River Mile: 93.6** | **Jacksonville District**

| Jan - Dec | Vessels Total | Vessels Rec. | Vessels Tows | Vessels Other | Barges Total | Barges Loaded | Barges Empty | Bottoms Total | Tonnage ktons |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | | |
| Upbound | 3,676 | 3,486 | 54 | 136 | 79 | 46 | 33 | 3,755 | 6 |
| Downbound | 3,953 | 3,792 | 28 | 133 | 33 | 25 | 8 | 3,986 | 5 |
| Total | 7,629 | 7,278 | 82 | 269 | 112 | 71 | 41 | 7,741 | 11 |
| **1994** | | | | | | | | | |
| Upbound | 3,862 | 3,693 | 59 | 110 | 70 | 55 | 15 | 3,932 | 22 |
| Downbound | 3,983 | 3,833 | 58 | 92 | 69 | 24 | 45 | 4,052 | 4 |
| Total | 7,845 | 7,526 | 117 | 202 | 139 | 79 | 60 | 7,984 | 26 |
| Percent Change | 3% | 3% | 43% | -25% | 24% | 11% | 46% | 3% | 136% |

| Jan - Dec | Lockages Total | Lockages Rec. | Lockages Comm. | Lockages Other | Number Delayed Tows | Average Delay All Tows (hrs) | Average Delay Delayed Tows (hrs) | Total Delay Time Tows (hrs) |
|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | |
| Upbound | 2,358 | 2,186 | 107 | 65 | 18 | 0.04 | 0.12 | 2.10 |
| Downbound | 2,553 | 2,414 | 66 | 73 | 8 | 0.04 | 0.13 | 1.00 |
| Total | 4,911 | 4,600 | 173 | 138 | 26 | 0.04 | 0.12 | 3.10 |
| **1994** | | | | | | | | |
| Upbound | 2,419 | 2,261 | 91 | 67 | 19 | 0.06 | 0.19 | 3.63 |
| Downbound | 2,551 | 2,411 | 93 | 47 | 22 | 0.13 | 0.33 | 7.28 |
| Total | 4,970 | 4,672 | 184 | 114 | 41 | 0.09 | 0.27 | 10.91 |
| Percent Change | 1% | 2% | 6% | -17% | 58% | 125% | 125% | 252% |

# LPMS Summary by Division/District

## January - December 1993 and 1994

**St. Lucie** **Main** **South Atlantic Divisior**
**Okeechobee** **River Mile: 15.3** **Jacksonville Distric**

| Jan - Dec | Vessels Total | Vessels Rec. | Vessels Tows | Vessels Other | Barges Total | Barges Loaded | Barges Empty | Bottoms Total | Tonnage ktons |
|---|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | | |
| Upbound | 4,117 | 3,767 | 82 | 268 | 95 | 52 | 43 | 4,212 | 7 |
| Downbound | 3,773 | 3,427 | 105 | 241 | 138 | 83 | 55 | 3,911 | 7 |
| Total | 7,890 | 7,194 | 187 | 509 | 233 | 135 | 98 | 8,123 | 14 |
| **1994** | | | | | | | | | |
| Upbound | 4,186 | 3,849 | 104 | 233 | 120 | 54 | 66 | 4,306 | 6 |
| Downbound | 3,940 | 3,596 | 106 | 238 | 117 | 85 | 32 | 4,057 | 30 |
| Total | 8,126 | 7,445 | 210 | 471 | 237 | 139 | 98 | 8,363 | 36 |
| Percent Change | 3% | 3% | 12% | -7% | 2% | 3% | 0% | 3% | 157% |

| Jan - Dec | Lockages Total | Lockages Rec. | Lockages Comm. | Lockages Other | Number Delayed Tows | Average Delay All Tows (hrs) | Average Delay Delayed Tows (hrs) | Total Delay Time Tows (hrs) |
|---|---|---|---|---|---|---|---|---|
| **1993** | | | | | | | | |
| Upbound | 2,597 | 2,322 | 99 | 176 | 73 | 0.21 | 0.24 | 17.17 |
| Downbound | 2,423 | 2,143 | 126 | 154 | 80 | 0.13 | 0.17 | 13.88 |
| Total | 5,020 | 4,465 | 225 | 330 | 153 | 0.17 | 0.20 | 31.05 |
| **1994** | | | | | | | | |
| Upbound | 2,495 | 2,230 | 124 | 141 | 102 | 0.24 | 0.24 | 24.53 |
| Downbound | 2,370 | 2,083 | 129 | 158 | 106 | 0.27 | 0.27 | 29.13 |
| Total | 4,865 | 4,313 | 253 | 299 | 208 | 0.26 | 0.26 | 53.66 |
| Percent Change | -3% | -3% | 12% | -9% | 36% | 53% | 30% | 73% |

# LPMS Summary by Division/District

## January - December 1994 and 1995

**Moore Haven** | **Main** | **South Atlantic Divisior**
**Caloosahatchee** | **River Mile: 78.0** | **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1994** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 5,058 | 4,814 | 80 | 164 | 90 | 73 | 17 | 5,148 | 25 |
| Downbound | 5,210 | 4,997 | 78 | 135 | 91 | 41 | 50 | 5,301 | 5 |
| Total | 10,268 | 9,811 | 158 | 299 | 181 | 114 | 67 | 10,449 | 30 |
| **1995** | | | | | | | | | |
| Upbound | 5,422 | 5,102 | 97 | 223 | 108 | 79 | 29 | 5,530 | 22 |
| Downbound | 5,629 | 5,334 | 80 | 215 | 88 | 40 | 48 | 5,717 | 5 |
| Total | 11,051 | 10,436 | 177 | 438 | 196 | 119 | 77 | 11,247 | 27 |
| Percent Change | 8% | 6% | 12% | 46% | 8% | 4% | 15% | 8% | -10% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | |
| **1994** | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 3,375 | 3,160 | 112 | 103 | 20 | 0.03 | 0.11 | 2.12 |
| Downbound | 3,368 | 3,175 | 107 | 86 | 12 | 0.01 | 0.09 | 1.10 |
| Total | 6,743 | 6,335 | 219 | 189 | 32 | 0.02 | 0.10 | 3.22 |
| **1995** | | | | | | | | |
| Upbound | 3,574 | 3,275 | 132 | 167 | 7 | 0.01 | 0.12 | 0.87 |
| Downbound | 3,558 | 3,290 | 106 | 162 | 5 | 0.01 | 0.21 | 1.03 |
| Total | 7,132 | 6,565 | 238 | 329 | 12 | 0.01 | 0.16 | 1.90 |
| Percent Change | 6% | 4% | 9% | 74% | -63% | -50% | 60% | -41% |

**W. P. Franklin** | **Main** | **South Atlantic Divisior**
**Caloosahatchee** | **River Mile: 122.0** | **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1994** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 7,695 | 7,486 | 56 | 153 | 73 | 58 | 15 | 7,768 | 27 |
| Downbound | 7,855 | 7,658 | 53 | 144 | 65 | 19 | 46 | 7,920 | 4 |
| Total | 15,550 | 15,144 | 109 | 297 | 138 | 77 | 61 | 15,688 | 31 |
| **1995** | | | | | | | | | |
| Upbound | 7,955 | 7,651 | 66 | 238 | 87 | 63 | 24 | 8,042 | 19 |
| Downbound | 8,112 | 7,832 | 55 | 225 | 71 | 21 | 50 | 8,183 | 3 |
| Total | 16,067 | 15,483 | 121 | 463 | 158 | 84 | 74 | 16,225 | 22 |
| Percent Change | 3% | 2% | 11% | 56% | 14% | 9% | 21% | 3% | -29% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | |
| **1994** | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 4,035 | 3,842 | 84 | 109 | 18 | 0.04 | 0.14 | 2.50 |
| Downbound | 4,209 | 4,033 | 78 | 98 | 16 | 0.05 | 0.16 | 2.48 |
| Total | 8,244 | 7,875 | 162 | 207 | 34 | 0.05 | 0.15 | 4.98 |
| **1995** | | | | | | | | |
| Upbound | 4,233 | 3,944 | 94 | 195 | 15 | 0.03 | 0.15 | 2.25 |
| Downbound | 4,430 | 4,159 | 75 | 196 | 10 | 0.03 | 0.17 | 1.70 |
| Total | 8,663 | 8,103 | 169 | 391 | 25 | 0.03 | 0.16 | 3.95 |
| Percent Change | 5% | 3% | 4% | 89% | -26% | -40% | 7% | -21% |

# LPMS Summary by Division/District
## January - December 1994 and 1995

**St. Lucie** | **Main** | **South Atlantic Divisior**
**Okeechobee** | **River Mile: 15.3** | **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1994** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,186 | 3,849 | 104 | 233 | 120 | 54 | 66 | 4,306 | 6 |
| Downbound | 3,940 | 3,596 | 106 | 238 | 117 | 85 | 32 | 4,057 | 30 |
| Total | 8,126 | 7,445 | 210 | 471 | 237 | 139 | 98 | 8,363 | 36 |
| **1995** | | | | | | | | | |
| Upbound | 4,855 | 4,372 | 113 | 370 | 128 | 73 | 55 | 4,983 | 9 |
| Downbound | 4,535 | 4,027 | 135 | 373 | 164 | 117 | 47 | 4,699 | 27 |
| Total | 9,390 | 8,399 | 248 | 743 | 292 | 190 | 102 | 9,682 | 36 |
| Percent Change | 16% | 13% | 18% | 58% | 23% | 37% | 4% | 16% | 0% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | |
| **1994** | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 2,495 | 2,230 | 124 | 141 | 102 | 0.24 | 0.24 | 24.53 |
| Downbound | 2,370 | 2,083 | 129 | 158 | 106 | 0.27 | 0.27 | 29.13 |
| Total | 4,865 | 4,313 | 253 | 299 | 208 | 0.26 | 0.26 | 53.66 |
| **1995** | | | | | | | | |
| Upbound | 2,961 | 2,641 | 143 | 177 | 102 | 0.20 | 0.22 | 22.52 |
| Downbound | 2,804 | 2,470 | 168 | 166 | 118 | 0.16 | 0.19 | 21.90 |
| Total | 5,765 | 5,111 | 311 | 343 | 220 | 0.18 | 0.20 | 44.42 |
| Percent Change | 18% | 19% | 23% | 15% | 6% | -31% | -23% | -17% |

# LPMS Summary by Division/District
## January - December 1994 and 1995

**Port Mayaca** | **Main** | **South Atlantic Divisior**
**Okeechobee** | **River Mile: 38.5** | **Jacksonville Districl**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| 1994 | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,797 | 3,584 | 52 | 1,161 | 68 | 21 | 47 | 4,865 | 3 |
| Downbound | 4,728 | 3,415 | 57 | 1,256 | 184 | 167 | 17 | 4,912 | 23 |
| Total | 9,525 | 6,999 | 109 | 2,417 | 252 | 188 | 64 | 9,777 | 26 |
| 1995 | | | | | | | | | |
| Upbound | 4,776 | 3,802 | 63 | 911 | 77 | 33 | 44 | 4,853 | 5 |
| Downbound | 4,608 | 3,581 | 75 | 952 | 151 | 125 | 26 | 4,759 | 21 |
| Total | 9,384 | 7,383 | 138 | 1,863 | 228 | 158 | 70 | 9,612 | 26 |
| Percent Change | -1% | 5% | 27% | -23% | -10% | -16% | 9% | -2% | 0% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | Time Tows |
| 1994 | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 3,796 | 2,706 | 1,027 | 63 | 2 | 0.01 | 0.14 | 0.28 |
| Downbound | 3,706 | 2,615 | 1,023 | 68 | 9 | 0.03 | 0.16 | 1.48 |
| Total | 7,502 | 5,321 | 2,050 | 131 | 11 | 0.02 | 0.16 | 1.76 |
| 1995 | | | | | | | | |
| Upbound | 3,316 | 2,523 | 680 | 113 | 7 | 0.01 | 0.12 | 0.82 |
| Downbound | 3,061 | 2,221 | 728 | 112 | 7 | 0.02 | 0.20 | 1.42 |
| Total | 6,377 | 4,744 | 1,408 | 225 | 14 | 0.02 | 0.16 | 2.24 |
| Percent Change | -15% | -11% | -31% | 72% | 27% | 0% | 0% | 27% |

**Ortona** | **Main** | **South Atlantic Divisior**
**Okeechobee** | **River Mile: 93.6** | **Jacksonville Districl**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| 1994 | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 3,862 | 3,693 | 59 | 110 | 70 | 55 | 15 | 3,932 | 22 |
| Downbound | 3,983 | 3,833 | 58 | 92 | 69 | 24 | 45 | 4,052 | 4 |
| Total | 7,845 | 7,526 | 117 | 202 | 139 | 79 | 60 | 7,984 | 26 |
| 1995 | | | | | | | | | |
| Upbound | 4,134 | 3,918 | 74 | 142 | 87 | 63 | 24 | 4,221 | 20 |
| Downbound | 4,367 | 4,160 | 64 | 143 | 71 | 28 | 43 | 4,438 | 4 |
| Total | 8,501 | 8,078 | 138 | 285 | 158 | 91 | 67 | 8,659 | 24 |
| Percent Change | 8% | 7% | 18% | 41% | 14% | 15% | 12% | 8% | -8% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | Time Tows |
| 1994 | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 2,419 | 2,261 | 91 | 67 | 19 | 0.06 | 0.19 | 3.63 |
| Downbound | 2,551 | 2,411 | 93 | 47 | 22 | 0.13 | 0.33 | 7.28 |
| Total | 4,970 | 4,672 | 184 | 114 | 41 | 0.09 | 0.27 | 10.91 |
| 1995 | | | | | | | | |
| Upbound | 2,604 | 2,402 | 115 | 87 | 30 | 0.07 | 0.18 | 5.50 |
| Downbound | 2,849 | 2,654 | 94 | 101 | 23 | 0.05 | 0.14 | 3.22 |
| Total | 5,453 | 5,056 | 209 | 188 | 53 | 0.06 | 0.16 | 8.72 |
| Percent Change | 10% | 8% | 14% | 65% | 29% | -33% | -41% | -20% |

# LPMS Summary by Division/District

## January - December 1995 and 1996

**Moore Haven** — **Caloosahatchee** — **Main** — **River Mile: 78.0** — **South Atlantic Division** — **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 5,422 | 5,102 | 97 | 223 | 108 | 79 | 29 | 5,530 | 22 |
| Downbound | 5,629 | 5,334 | 80 | 215 | 88 | 40 | 48 | 5,717 | 5 |
| Total | 11,051 | 10,436 | 177 | 438 | 196 | 119 | 77 | 11,247 | 27 |
| **1996** | | | | | | | | | |
| Upbound | 5,287 | 5,054 | 70 | 163 | 84 | 65 | 19 | 5,371 | 9 |
| Downbound | 5,441 | 5,220 | 73 | 148 | 84 | 48 | 36 | 5,525 | 7 |
| Total | 10,728 | 10,274 | 143 | 311 | 168 | 113 | 55 | 10,896 | 16 |
| Percent Change | -3% | -2% | -19% | -29% | -14% | -5% | -29% | -3% | -41% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | Time Tows |
| **1995** | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 3,574 | 3,275 | 132 | 167 | 7 | 0.01 | 0.12 | 0.87 |
| Downbound | 3,558 | 3,290 | 106 | 162 | 5 | 0.01 | 0.21 | 1.03 |
| Total | 7,132 | 6,565 | 238 | 329 | 12 | 0.01 | 0.16 | 1.90 |
| **1996** | | | | | | | | |
| Upbound | 3,292 | 3,069 | 94 | 129 | 7 | 0.01 | 0.11 | 0.75 |
| Downbound | 3,276 | 3,074 | 95 | 107 | 5 | 0.01 | 0.16 | 0.78 |
| Total | 6,568 | 6,143 | 189 | 236 | 12 | 0.01 | 0.13 | 1.53 |
| Percent Change | -8% | -6% | -21% | -28% | 0% | 0% | -19% | -19% |

**W. P. Franklin** — **Caloosahatchee** — **Main** — **River Mile: 122.0** — **South Atlantic Division** — **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 7,955 | 7,651 | 66 | 238 | 87 | 63 | 24 | 8,042 | 19 |
| Downbound | 8,112 | 7,832 | 55 | 225 | 71 | 21 | 50 | 8,183 | 3 |
| Total | 16,067 | 15,483 | 121 | 463 | 158 | 84 | 74 | 16,225 | 22 |
| **1996** | | | | | | | | | |
| Upbound | 8,115 | 7,872 | 46 | 197 | 66 | 47 | 19 | 8,181 | 8 |
| Downbound | 8,362 | 8,141 | 51 | 170 | 75 | 36 | 39 | 8,437 | 5 |
| Total | 16,477 | 16,013 | 97 | 367 | 141 | 83 | 58 | 16,618 | 13 |
| Percent Change | 3% | 3% | -20% | -21% | -11% | -1% | -22% | 2% | -41% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay |
|---|---|---|---|---|---|---|---|---|
| | | | | | | All Tows | Delayed Tows | Time Tows |
| **1995** | Total | Rec. | Comm. | Other | Tows | (hrs) | (hrs) | (hrs) |
| Upbound | 4,233 | 3,944 | 94 | 195 | 15 | 0.03 | 0.15 | 2.25 |
| Downbound | 4,430 | 4,159 | 75 | 196 | 10 | 0.03 | 0.17 | 1.70 |
| Total | 8,663 | 8,103 | 169 | 391 | 25 | 0.03 | 0.16 | 3.95 |
| **1996** | | | | | | | | |
| Upbound | 4,118 | 3,885 | 68 | 165 | 16 | 0.09 | 0.26 | 4.13 |
| Downbound | 4,268 | 4,061 | 66 | 141 | 16 | 0.09 | 0.28 | 4.43 |
| Total | 8,386 | 7,946 | 134 | 306 | 32 | 0.09 | 0.27 | 8.56 |
| Percent Change | -3% | -2% | -21% | -22% | 28% | 200% | 69% | 117% |

# LPMS Summary by Division/District

## January - December 1995 and 1996

**Port Mayaca** — **Main** — **South Atlantic Division**
**Okeechobee** — **River Mile: 38.5** — **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,776 | 3,802 | 63 | 911 | 77 | 33 | 44 | 4,853 | 5 |
| Downbound | 4,608 | 3,581 | 75 | 952 | 151 | 125 | 26 | 4,759 | 21 |
| Total | 9,384 | 7,383 | 138 | 1,863 | 228 | 158 | 70 | 9,612 | 26 |
| **1996** | | | | | | | | | |
| Upbound | 4,420 | 3,448 | 54 | 918 | 67 | 34 | 33 | 4,487 | 5 |
| Downbound | 4,348 | 3,349 | 49 | 950 | 89 | 69 | 20 | 4,437 | 8 |
| Total | 8,768 | 6,797 | 103 | 1,868 | 156 | 103 | 53 | 8,924 | 13 |
| Percent Change | -7% | -8% | -25% | 0% | -32% | -35% | -24% | -7% | -50% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Comm. | Other | Tows | All Tows (hrs) | Delayed Tows (hrs) | (hrs) |
| Upbound | 3,316 | 2,523 | 680 | 113 | 7 | 0.01 | 0.12 | 0.82 |
| Downbound | 3,061 | 2,221 | 728 | 112 | 7 | 0.02 | 0.20 | 1.42 |
| Total | 6,377 | 4,744 | 1,408 | 225 | 14 | 0.02 | 0.16 | 2.24 |
| **1996** | | | | | | | | |
| Upbound | 2,936 | 2,105 | 234 | 597 | 12 | 0.04 | 0.16 | 1.95 |
| Downbound | 2,795 | 1,968 | 249 | 578 | 6 | 0.04 | 0.37 | 2.20 |
| Total | 5,731 | 4,073 | 483 | 1,175 | 18 | 0.04 | 0.23 | 4.15 |
| Percent Change | -10% | -14% | -66% | 422% | 29% | 100% | 44% | 85% |

**Ortona** — **Main** — **South Atlantic Division**
**Okeechobee** — **River Mile: 93.6** — **Jacksonville District**

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,134 | 3,918 | 74 | 142 | 87 | 63 | 24 | 4,221 | 20 |
| Downbound | 4,367 | 4,160 | 64 | 143 | 71 | 28 | 43 | 4,438 | 4 |
| Total | 8,501 | 8,078 | 138 | 285 | 158 | 91 | 67 | 8,659 | 24 |
| **1996** | | | | | | | | | |
| Upbound | 3,925 | 3,744 | 54 | 127 | 70 | 57 | 13 | 3,995 | 9 |
| Downbound | 4,090 | 3,921 | 54 | 115 | 70 | 37 | 33 | 4,160 | 4 |
| Total | 8,015 | 7,665 | 108 | 242 | 140 | 94 | 46 | 8,155 | 13 |
| Percent Change | -6% | -5% | -22% | -15% | -11% | 3% | -31% | -6% | -46% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| **1995** | Total | Rec. | Comm. | Other | Tows | All Tows (hrs) | Delayed Tows (hrs) | (hrs) |
| Upbound | 2,604 | 2,402 | 115 | 87 | 30 | 0.07 | 0.18 | 5.50 |
| Downbound | 2,849 | 2,654 | 94 | 101 | 23 | 0.05 | 0.14 | 3.22 |
| Total | 5,453 | 5,056 | 209 | 188 | 53 | 0.06 | 0.16 | 8.72 |
| **1996** | | | | | | | | |
| Upbound | 2,356 | 2,188 | 62 | 106 | 21 | 0.14 | 0.36 | 7.58 |
| Downbound | 2,467 | 2,313 | 65 | 89 | 14 | 0.06 | 0.23 | 3.22 |
| Total | 4,823 | 4,501 | 127 | 195 | 35 | 0.10 | 0.31 | 10.80 |
| Percent Change | -12% | -11% | -39% | 4% | -34% | 67% | 94% | 24% |

# LPMS Summary by Division/District
## January - December 1995 and 1996

| St. Lucie<br>Okeechobee | Main<br>River Mile: 15.3 | South Atlantic Division<br>Jacksonville District |
|---|---|---|

| Jan - Dec | Vessels | | | | Barges | | | Bottoms | Tonnage |
|---|---|---|---|---|---|---|---|---|---|
| 1995 | Total | Rec. | Tows | Other | Total | Loaded | Empty | Total | ktons |
| Upbound | 4,855 | 4,372 | 113 | 370 | 128 | 73 | 55 | 4,983 | 9 |
| Downbound | 4,535 | 4,027 | 135 | 373 | 164 | 117 | 47 | 4,699 | 27 |
| Total | 9,390 | 8,399 | 248 | 743 | 292 | 190 | 102 | 9,682 | 36 |
| 1996 | | | | | | | | | |
| Upbound | 4,500 | 3,859 | 116 | 525 | 134 | 82 | 52 | 4,634 | 8 |
| Downbound | 4,444 | 3,759 | 110 | 575 | 122 | 95 | 27 | 4,566 | 15 |
| Total | 8,944 | 7,618 | 226 | 1,100 | 256 | 177 | 79 | 9,200 | 23 |
| Percent Change | -5% | -9% | -9% | 48% | -12% | -7% | -23% | -5% | -36% |

| Jan - Dec | Lockages | | | | Number Delayed | Average Delay | | Total Delay Time Tows |
|---|---|---|---|---|---|---|---|---|
| 1995 | Total | Rec. | Comm. | Other | Tows | All Tows (hrs) | Delayed Tows (hrs) | (hrs) |
| Upbound | 2,961 | 2,641 | 143 | 177 | 102 | 0.20 | 0.22 | 22.52 |
| Downbound | 2,804 | 2,470 | 168 | 166 | 118 | 0.16 | 0.19 | 21.90 |
| Total | 5,765 | 5,111 | 311 | 343 | 220 | 0.18 | 0.20 | 44.42 |
| 1996 | | | | | | | | |
| Upbound | 2,469 | 2,119 | 127 | 223 | 51 | 0.13 | 0.30 | 15.22 |
| Downbound | 2,457 | 2,090 | 118 | 249 | 50 | 0.13 | 0.29 | 14.52 |
| Total | 4,926 | 4,209 | 245 | 472 | 101 | 0.13 | 0.29 | 29.74 |
| Percent Change | -15% | -18% | -21% | 38% | -54% | -28% | 45% | -33% |

# Comprehensive Location Map

## LEGEND

- Cattail
- Torpedograss
- Spikerush
- Hydrilla
- Glades County Roads
- Glades County Hydrology
- Lake Okeechobee
- Glades County

**Herpetofaunal Drift Fences**

| | |
|---|---|
| DFC | Cattail |
| DFDE | Dry Spikerush |
| DFWE | Wet Spikerush |
| DFDT | Dry Torpedograss |

**Avifaunal Transects**

| | |
|---|---|
| CAT | Cattail |
| DE | Dry Spikerush |
| WE | Wet Spikerush |
| DT | Dry Torpedograss |
| WT | Wet Torpedograss |
| HY-FL | Floating Hydrilla |
| HY-SU | Submerged Hydrilla |

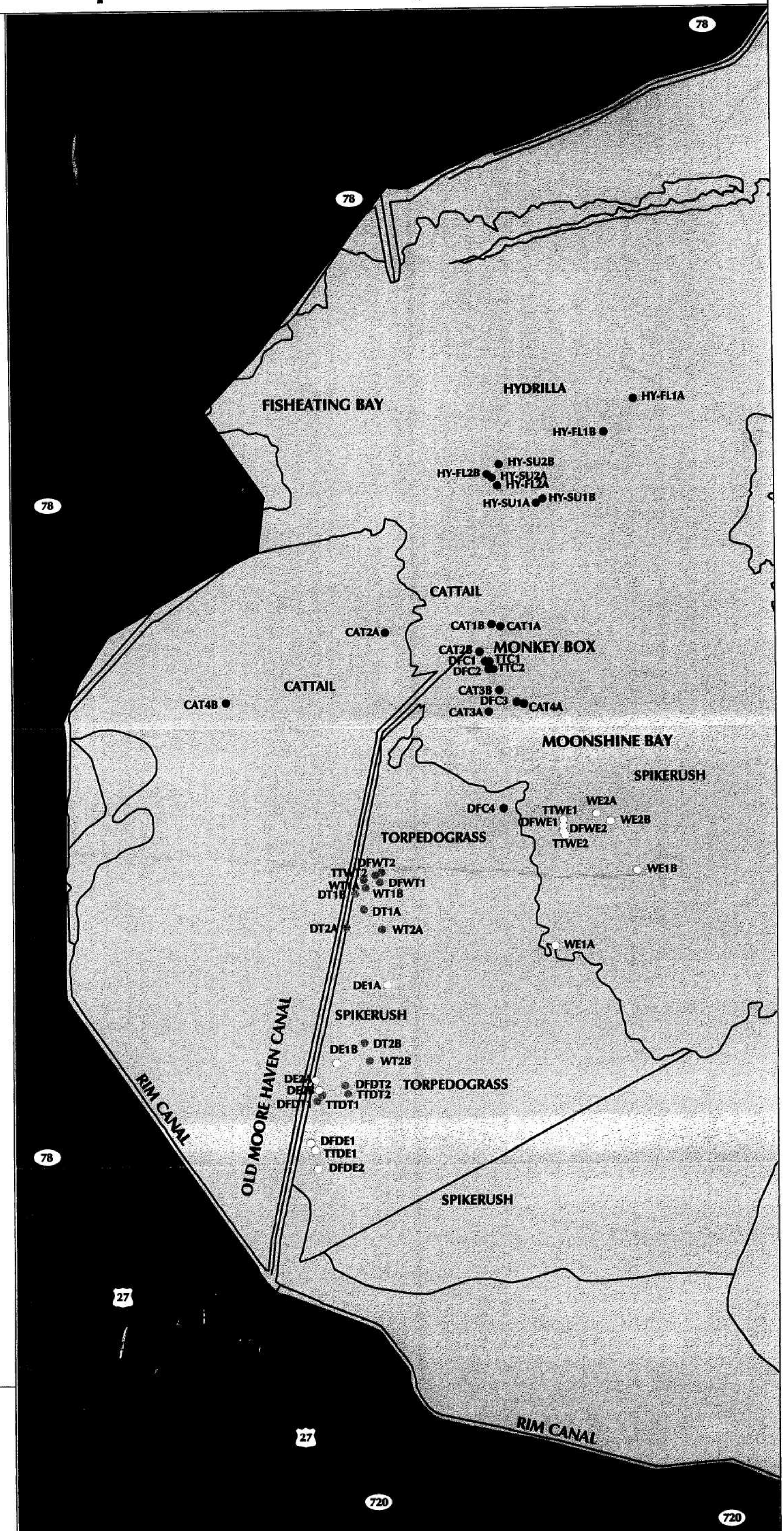
**Turtle Trap Arrays**

| | |
|---|---|
| TTC | Cattail |
| TTDE | Dry Spikerush |
| TTWE | Wet Spikerush |
| TTDT | Dry Torpedograss |
| TTWT | Wet Torpedograss |

N

SCALE 1 Inch = 1 Mile

0 1 2 Miles




**MAP DATA & PROJECTION INFORMATION**

BASE MAP PROVIDED BY THE SFWMD
COORDINATE SYSTEM: STATE PLANE
DATUM: NAD27
ZONE: 3601 (EAST ZONE)
MAP UNITS: FEET

PREPARED BY LOTSPEICH & ASSOCIATES, INC.
DATE OF PRINT 6/30/99

# Herpetofaunal Drift Fences

## LEGEND

- ● Drift Fence Location

- Australian Pine
- Melaleuca
- Wax Myrtle
- Brazilian Pepper
- Willow
- Button Bush
- 9
- Nut Sedge
- Phragmites
- Nymphaea/Eleocharis
- Bulrush
- Cattail
- Sawgrass
- Cat/Nymphaea
- Cat/Pont/Sag/Spar
- Eleocharis
- Nymphaea
- Spatterdock
- Lotus
- Spartina
- Spar/mixed grass
- Mixed grass
- Herbicide Impacted
- Torpedograss
- Polygonum
- Eleocharis/Torpedograss
- Dispersed veg/Open water
- Open water/Dispersed veg
- Open water
- Permanent Disturbed
- 35
- 36
- Mixed Forest
- 246

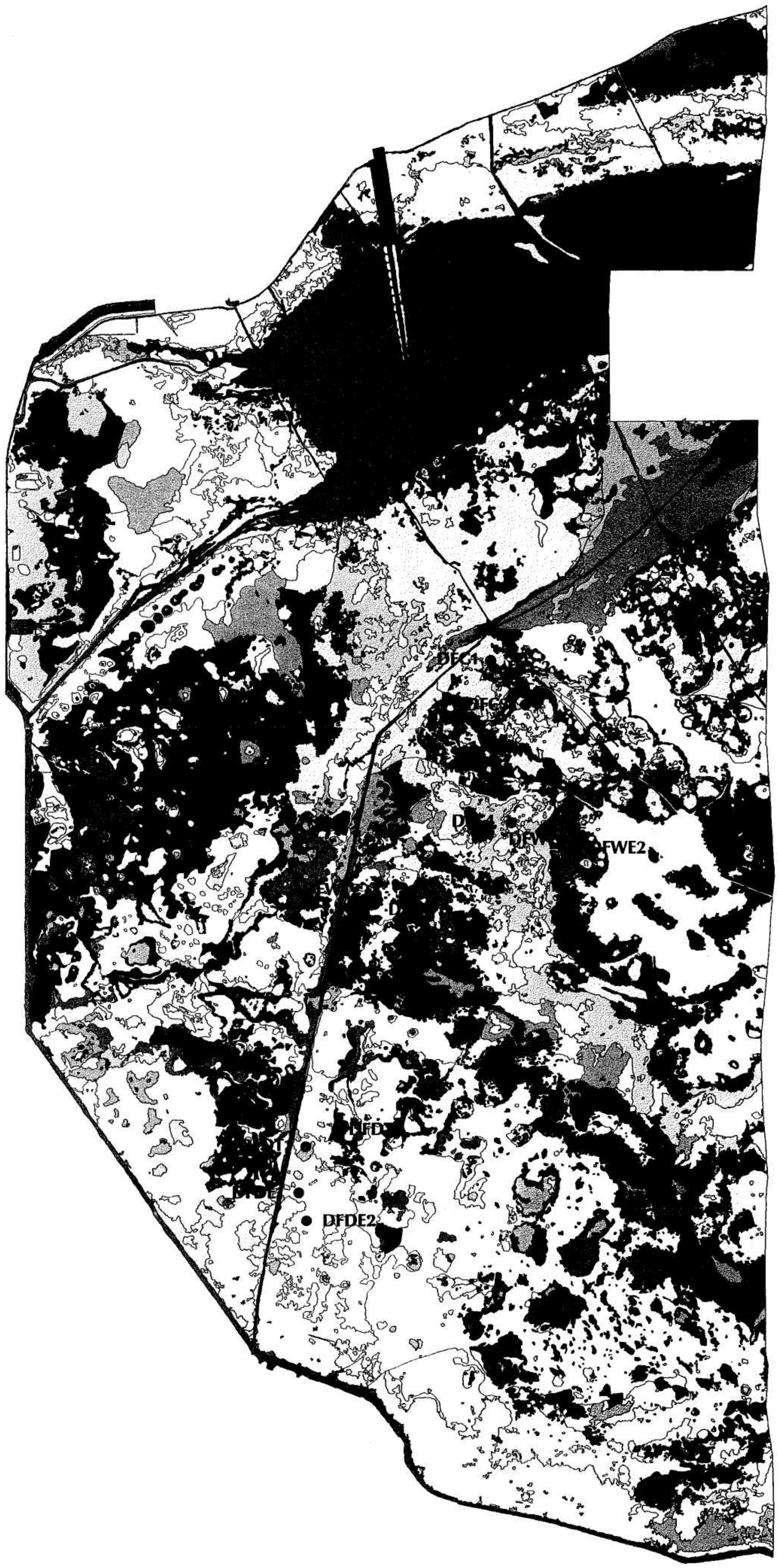
**Herpetofaunal Drift Fences**

| | |
|---|---|
| DFC | Cattail |
| DFDE | Dry Spikerush |
| DFWE | Wet Spikerush |
| DFDT | Dry Torpedograss |

N

SCALE 1 Inch = 1 Mile

0 1 2 Miles




**MAP DATA & PROJECTION INFORMATION**

BASE MAP PROVIDED BY THE SFWMD

COORDINATE SYSTEM: STATE PLANE
DATUM: NAD27
ZONE: 3601 (EAST ZONE)
MAP UNITS: FEET

PREPARED BY LOTSPEICH & ASSOCIATES, INC.
DATE OF PRINT 6/30/99

# Avfaunal Transects (Point A)

## LEGEND

- Transect Point A
- Australian Pine
- Melaleuca
- Wax Myrtle
- Brazilian Pepper
- Willow
- Button Bush
- 9
- Nut Sedge
- Phragmites
- Nymphaea/Eleocharis
- Bulrush
- Cattail
- Sawgrass
- Cat/Nymphaea
- Cat/Pont/Sag/Spar
- Eleocharis
- Nymphaea
- Spatterdock
- Lotus
- Spartina
- Spar/mixed grass
- Mixed grass
- Herbicide Impacted
- Torpedograss
- Polygonum
- Eleocharis/Torpedograss
- Dispersed veg/Open water
- Open water/Dispersed veg
- Open water
- Permanent Disturbed
- 35
- 36
- Mixed Forest
- 246

**Avifaunal Transects**

| | |
|---|---|
| CAT | Cattail |
| DE | Dry Spikerush |
| WE | Wet Spikerush |
| DT | Dry Torpedograss |
| WT | Wet Torpedograss |
| HY-FL | Floating Hydrilla |
| HY-SU | Submerged Hydrilla |


N

SCALE 1 Inch = 1 Mile

0 1 2 Miles

MAP DATA & PROJECTION INFORMATION

BASE MAP PROVIDED BY THE SFWMD

COORDINATE SYSTEM: STATE PLANE
DATUM: NAD27
ZONE: 3601 (EAST ZONE)
MAP UNITS: FEET

PREPARED BY LOTSPEICH & ASSOCIATES, INC.
DATE OF PRINT 6/30/99

# Avfaunal Transects (Point B)

## LEGEND

- Transect Point B
- Australian Pine
- Melaleuca
- Wax Myrtle
- Brazilian Pepper
- Willow
- Button Bush
- 9
- Nut Sedge
- Phragmites
- Nymphaea/Eleocharis
- Bulrush
- Cattail
- Sawgrass
- Cat/Nymphaea
- Cat/Pont/Sag/Spar
- Eleocharis
- Nymphaea
- Spatterdock
- Lotus
- Spartina
- Spar/mixed grass
- Mixed grass
- Herbicide Impacted
- Torpedograss
- Polygonum
- Eleocharis/Torpedograss
- Dispersed veg/Open water
- Open water/Dispersed veg
- Open water
- Permanent Disturbed
- 35
- 36
- Mixed Forest
- 246

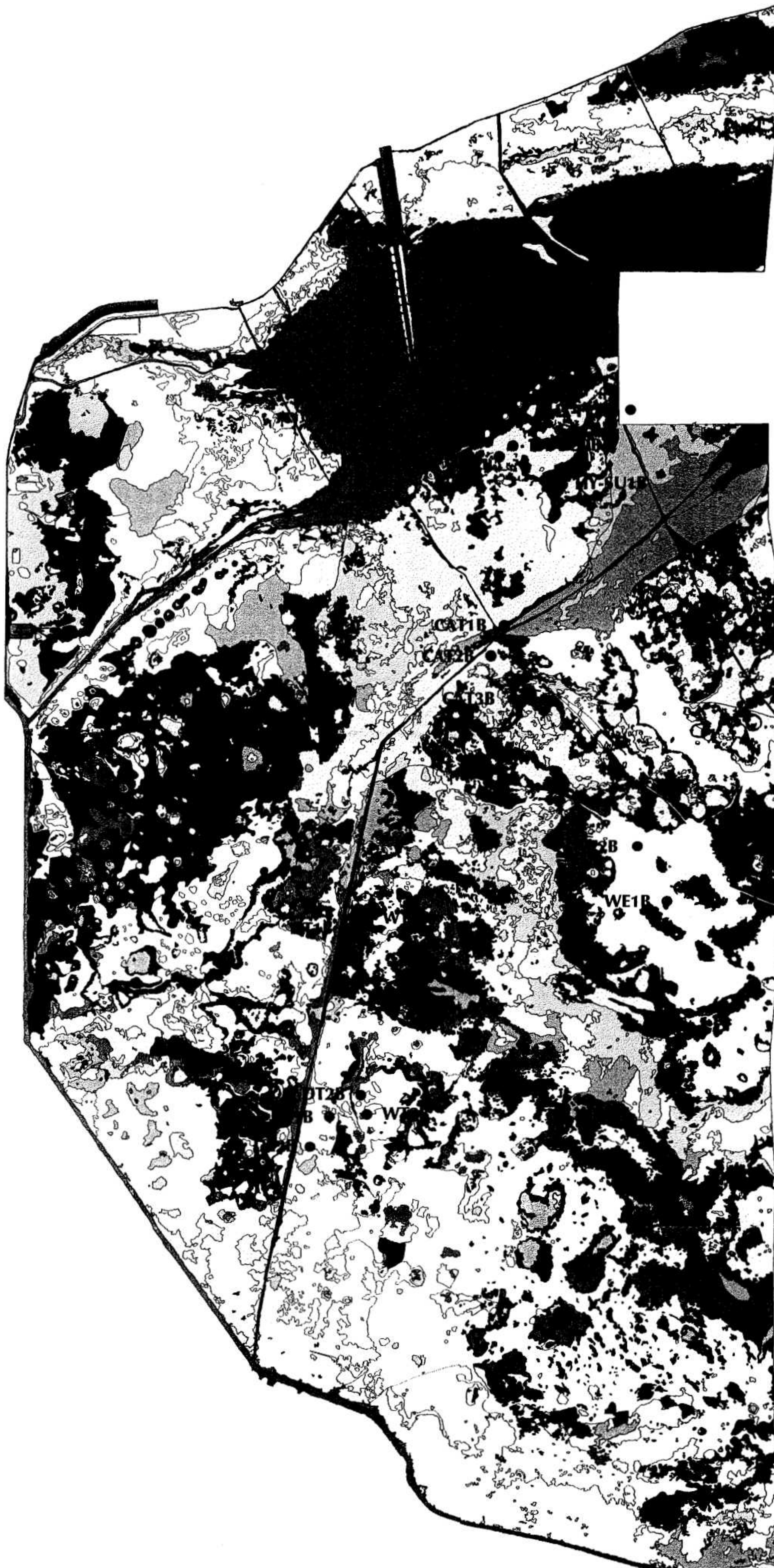
Avifaunal Transects

| | |
|---|---|
| CAT | Cattail |
| DE | Dry Spikerush |
| WE | Wet Spikerush |
| DT | Dry Torpedograss |
| WT | Wet Torpedograss |
| HY-FL | Floating Hydrilla |
| HY-SU | Submerged Hydrilla |

N

SCALE 1 Inch = 1 Mile

0 1 2 Miles




MAP DATA & PROJECTION INFORMATION

BASE MAP PROVIDED BY THE SFWMD

COORDINATE SYSTEM: STATE PLANE
DATUM: NAD27
ZONE: 3601 (EAST ZONE)
MAP UNITS: FEET

PREPARED BY LOTSPEICH & ASSOCIATES, INC.
DATE OF PRINT 6/30/99

# Turtle Traps

## LEGEND

- Turtle Trap Array

| | |
|---|---|
| | Australian Pine |
| | Melaleuca |
| | Wax Myrtle |
| | |
| | Brazilian Pepper |
| | Willow |
| | Button Bush |
| | 9 |
| | Nut Sedge |
| | Phragmites |
| | Nymphaea/Eleocharis |
| | Bulrush |
| | Cattail |
| | Sawgrass |
| | Cat/Nymphaea |
| | Cat/Pont/Sag/Spar |
| | Eleocharis |
| | Nymphaea |
| | Spatterdock |
| | Lotus |
| | Spartina |
| | Spar/mixed grass |
| | Mixed grass |
| | Herbicide Impacted |
| | Torpedograss |
| | Polygonum |
| | Eleocharis/Torpedograss |
| | Dispersed veg/Open water |
| | Open water/Dispersed veg |
| | Open water |
| | Permanent Disturbed |
| | 35 |
| | 36 |
| | Mixed Forest |
| | 246 |

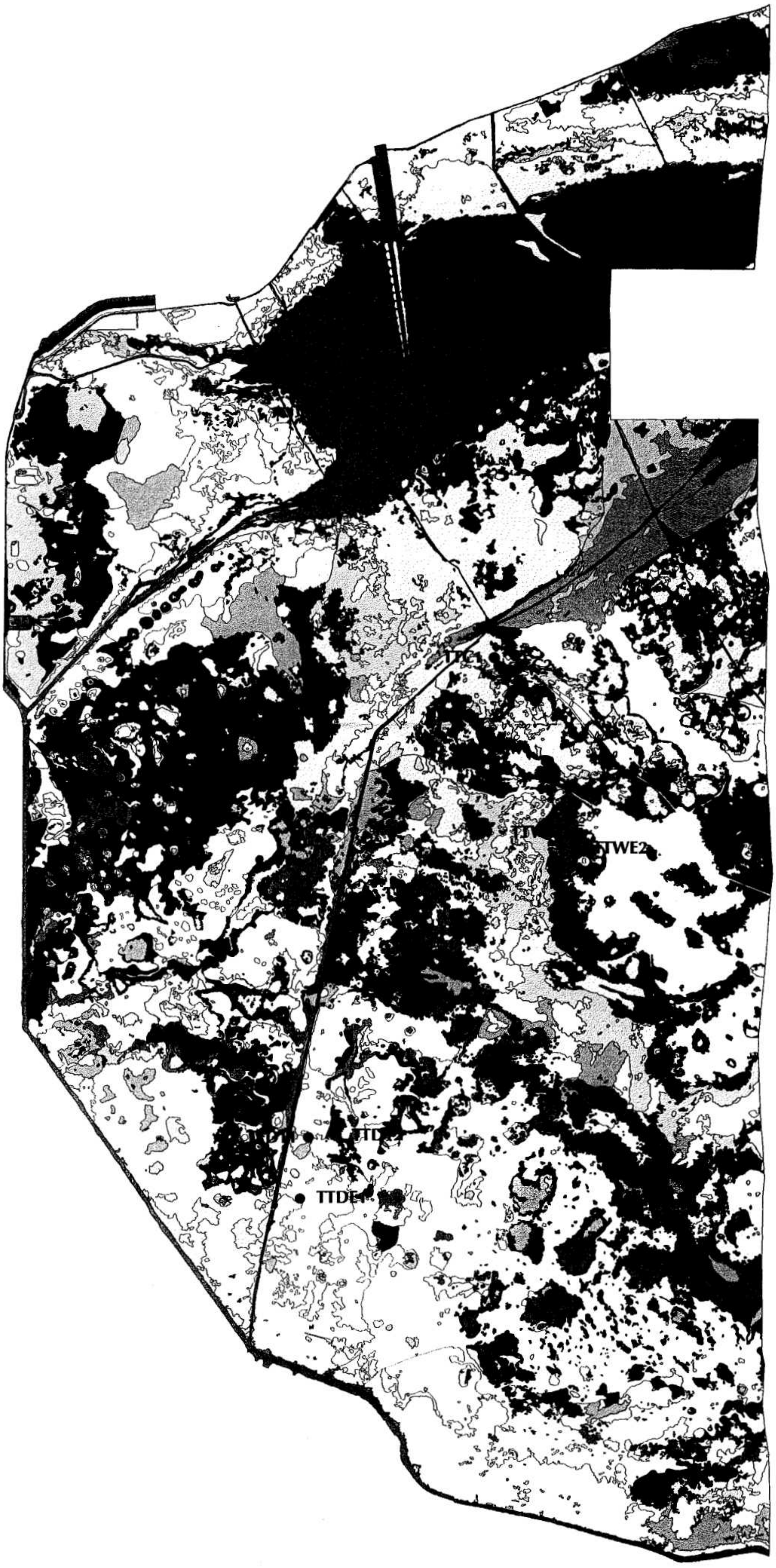
**Turtle Trap Arrays**

| | |
|---|---|
| TTC | Cattail |
| TTDE | Dry Spikerush |
| TTWE | Wet Spikerush |
| TTDT | Dry Torpedograss |
| TTWT | Wet Torpedograss |

N

SCALE 1 Inch = 1 Mile

0 1 2 Miles




**MAP DATA & PROJECTION INFORMATION**

BASE MAP PROVIDED BY THE SFWMD

COORDINATE SYSTEM: STATE PLANE
DATUM: NAD27
ZONE: 3601 (EAST ZONE)
MAP UNITS: FEET

PREPARED BY LOTSPEICH & ASSOCIATES, INC.
DATE OF PRINT 6/30/99

# APPENDIX C

## LICENSE PLATE SURVEY – LAKE OKEECHOBEE BOAT RAMPS
## 22, 23 NOVEMBER 1997

Lake Okeechobee Ramps　　License Plate Survey　　22 November 1997

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Lic. Plates | Old | Alvin | Morre | Sport's | Lake | Hamie | Bare | Dyess | Indian | Okee. | Nubbin | Okie- | C.Scott | Port | Indian | Canal Pt. | Paul Rardin | S.Bay, Stretch Pk. | |
| 2 | 11/22/97 | Joe's | Ward | Haven | Village | Port | Pond | Beach | Canal | Prarie | | Slough | Tanti | Driver | Mayaca | town | | J-Mark, Slim's | J.Roger, Clewis., R. Martin | total |
| 3 | Brevard | | 1 | | | | | 1 | | 2 | | | | | | | | | | 4 |
| 4 | Broward | 9 | 15 | 11 | 3 | 3 | 3 | 19 | 5 | | | | | | | | | 17 | 6 | 91 |
| 5 | Charlotte | | | | | | | 2 | | | | | 3 | | | | | 3 | | 8 |
| 6 | Citrus | | 1 | | | | | | | 1 | | | 1 | | | | | | | 3 |
| 7 | Collier | | 2 | | | | | 1 | | | | | | | | | | | 2 | 5 |
| 8 | Columbia | | | | | | | 1 | | | | | | | | | | | | 1 |
| 9 | Dade | | 3 | | 3 | 1 | | 2 | 4 | | | | 1 | | | | | | | 14 |
| 10 | Duval | | | | | | | | 1 | | | | | | | | | | | 1 |
| 11 | Desoto | | | | | | | | | | | | 1 | | | | | | | 1 |
| 12 | Glades | | 1 | 1 | | 3 | 2 | 12 | 4 | | | | 1 | | | | | | | 24 |
| 13 | Hardee | | | | | | 1 | | | | | | | | | | | | | 1 |
| 14 | Hendry | | 1 | | | 3 | 1 | 4 | 1 | | | | 1 | 1 | | | | 1 | 4 | 17 |
| 15 | Highlands | | 1 | | | | | | 1 | 2 | | | 1 | 2 | | | | | | 7 |
| 16 | Hillsborough | 1 | | | | | | 3 | | | | | 6 | | | | | | | 10 |
| 17 | Lake | | 4 | 1 | | | | 1 | | | | | 1 | | | | | | | 7 |
| 18 | Lee | | | 1 | 2 | 1 | 1 | 17 | 1 | | | | 2 | | | | | | | 25 |
| 19 | Manatee | | | | | | | 5 | 3 | | | | 1 | | | | | | | 9 |
| 20 | Marion | | | | | | | | 1 | | | | | | | | | | 1 | 2 |
| 21 | Martin | | | 1 | 1 | | | 7 | 5 | | | | 3 | | | | | 1 | | 18 |
| 22 | Monroe | | | | | | | | 1 | | | | | | | | | | | 1 |
| 23 | Okeechobee | | | | | | | 8 | 9 | 3 | 20 | 1 | 31 | 6 | | | 7 | 1 | | 86 |
| 24 | Okaloosa | | | | | | | | | | | | | | | | | | | 0 |
| 25 | Orange | | 1 | | | | | 3 | | | | | 2 | | | | | | | 6 |
| 26 | Osceola | | | | | | | | 1 | | | | | | | | | | | 1 |
| 27 | Palm Beach | 2 | 6 | 3 | 2 | 2 | 1 | 9 | 9 | 2 | 5 | | 7 | 1 | | 1 | | 4 | | 54 |
| 28 | Pascoe | | | | | | | | | | | | 3 | | | | 1 | | | 4 |
| 29 | Pinellas | | 1 | | | 1 | | 2 | | | | | 1 | 1 | | | | | | 6 |
| 30 | Polk | | | | | | | 1 | 1 | | | | 1 | | 1 | | | | | 4 |
| 31 | Putnam | | | | | | | | | | | | 2 | | | | | | 1 | 3 |
| 32 | Sarasota | | | | | | | 6 | 1 | | | | | | | | | | | 7 |
| 33 | Seminole | | | | | | | | | | | | | | | | 1 | | | 1 |
| 34 | St. Lucie | | | 1 | | | 1 | 4 | 1 | 2 | 4 | | 7 | | | | 1 | 2 | | 23 |
| 35 | Valousia | 1 | | 1 | | | | | | | | | | | | | | | | 2 |
| 36 | Florida | 4 | 6 | 16 | 5 | 4 | 3 | 17 | 10 | | 2 | | 8 | | | | 1 | 2 | 3 | 83 |
| 37 | | | | | | | | | | | | | | | | | | | | |

| | A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R | S | T |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38 | Alabama | | 1 | | | | | | | | 1 | | 1 | | | | | | | 3 |
| 39 | Georgia | | | | | | | | 1 | | | | | | | | | | | 1 |
| 40 | Illinois | | | | | | | | | 1 | 1 | | | | | | | | | 2 |
| 41 | Indiana | | | | | | | | | | 1 | | 1 | | | | | | | 2 |
| 42 | Kentucky | | | | | | | 2 | 1 | | 2 | | 2 | 1 | | | | | | 8 |
| 43 | Ohio | | | | | | | 1 | 1 | | 1 | | 4 | | | | | | 1 | 8 |
| 44 | Maine | | | | | | | | | | 1 | | | | | | | | 1 | 2 |
| 45 | Michigan | | | | | | | | | | 1 | | | 3 | | | | | | 4 |
| 46 | Missouri | | | | | | | | 1 | | | | | | | | | | 1 | 2 |
| 47 | N.Carolina | | | | | | | | | | | | | 2 | | | | | | 2 |
| 48 | S.Carolina | | | | | | | | | | | | | | | | | 1 | | 1 |
| 49 | Tenn. | | | | | | | | 1 | 2 | 1 | | 1 | | | | | | | 5 |
| 50 | Total | 17 | 46 | 36 | 16 | 18 | 13 | 128 | 64 | 15 | 40 | 1 | 93 | 17 | 1 | 1 | 11 | 32 | 20 | 569 |
| 51 | V's. Docked | | | 7 | | | | | | | | | | | | 35 | 28 | 25 | 44 | 139 |
| 52 | Space Left | 0 | 150 | 50 | 20 | 10 | 5 | 50 | 0 | 25 | 40 | 80 | 100 | 20 | 150 | 0 | 20 | 60 | 165 | 945 |

# APPENDIX D

# SPOT SOUNDINGS – LAKE OKEECHOBEE BOAT RAMPS
# 22, 23 NOVEMBER 1997

Lake Okeechobee
Boat Ramps

Spot Soundings

22 23 Nov 1997
Lake Stage: 15.3' NGVD

| Boat Ramps | Depth |
|---|---|
| Clewiston city ramp | 10 |
| Slim's Fish Camp | 9.6 |
| Sportsman's Grove | 9.6 |
| Public Ramp at Slim's | 8.8 |
| Slim's Fish Camp | 7.6 |
| Alvin Ward | 7.5 |
| Okie-Tanti Recreation Area | 7.4 |
| Uncle Joe's Liberty Point | 7.2 |
| South Bay | 7 |
| Dias Canal Ramp 2 | 6.9 |
| Pahokee | 6.7 |
| John's Stretch | 6.1 |
| Indiantown Marina | 6.1 |
| Harney Pond Canal | 5.8 |
| Clewiston | 5.2 |
| Moore Haven Rec. Center | 5 |
| COE Clewiston | 5 |
| Dias Canal Ramp 1 | 5 |
| Indiantown Park | 4.3 |
| Canal Point | 4.1 |
| J-Mark Fish Camp | 3.6 |

# APPENDIX E

# SPORT FISHING SEASONS

## SPORT FISH SEASONS
## LAKE OKEECHOBEE

| | Largemouth Bass | Black Crappie | Sunshine Bass | Bream |
|---|---|---|---|---|
| January | Fair – Good | Excellent | Good | Poor |
| February | Excellent | Excellent | Good | Poor |
| March | Excellent | Good | Good | Fair |
| April | Good | Fair | Fair | Fair – Good |
| May | Good | Poor | Poor | Good |
| June | Fair – Good | Poor | Poor | Good |
| July | Fair – Good | Poor | Poor | Good |
| August | Fair – Good | Poor | Poor | Good |
| September | Fair – Good | Poor | Poor – Fair | Good |
| October | Fair – Good | Poor - Fair | Poor – Fair | Poor - Fair |
| November | Fair | Fair – Good | Excellent | Poor |
| December | Fair | Excellent | Excellent | Poor |

# APPENDIX E

# WILDLIFE SURVEY and HABITAT UTILIZATION STUDY of WESTERN LITTORAL ZONE, LAKE OKEECHOBEE, FLORIDA

# U.S. Army Corps of Engineers
# Jacksonville District

# Wildlife Survey and Habitat Utilization Study of Western Littoral Zone, Lake Okeechobee, Florida

**Final Report**
**June 1999**

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# WILDLIFE SURVEY AND HABITAT UTILIZATION STUDY OF WESTERN LITTORAL ZONE, LAKE OKEECHOBEE, FLORIDA

## I. INTRODUCTION

Lake Okeechobee, one of the largest freshwater ecosystems in North America (approximately 1,750 square kilometers ($km^2$)), is unique due to its shallowness and expansive littoral zone (approximately 400 $km^2$) (Figure 1). The hydrology of this system is of great importance due to its value to recreational interests, water supply, and providing habitat for hundreds of species of wildlife. Lotspeich and Associates, Inc. (L&A), under contract to the U.S. Army Corps of Engineers, Jacksonville District (Corps), has conducted a two year study to collect baseline wildlife data within the littoral zone of Lake Okeechobee. The data were collected for the purpose of determining habitat preferences of wildlife communities of the Lake Okeechobee marsh and littoral zone, and to evaluate water level and hydroperiod influences upon preferred habitat. These data will assist managers in selecting a regulation schedule that optimizes the ecological values of the Lake ecosystem.

The study area lies within the western littoral zone and marsh of Lake Okeechobee and extends from the rim canal adjacent to the Herbert Hoover Dike (HHD), east to the littoral zone/lake interface, south to the Mayaca Cut, and north to Fisheating Bay (Figure 1).

This is the final report, a culmination of eight separate week-long sampling events conducted from May 1997 to November 1998. This report provides a general overview of the study area, descriptions of ambient environmental conditions experienced during each sampling event and at each sampling location, and analyses of the data resulting from the eight sampling events. The report also addresses possible relationships between vegetative community types and wildlife utilization coincident with various lake levels encountered during the sampling events.

The Lake Okeechobee Regulation Schedule Study (LORSS) is considering a range of alternative lake regulation schedules and will ultimately select a schedule which provides optimal environmental benefits at minimal or no impact to competing the study's purposes, such as flood control and water supply.

The goal of the LORSS currently being conducted by the Corps and South Florida Water Management District (SFWMD) is to optimize environmental benefits at minimal or no impact to the competing study's purposes, primarily flood control and water supply. As part of the LORSS, this study was initiated to evaluate relationships between wildlife and lake levels, and other parameters measured during sampling within the western littoral zone. Two taxonomic groups of wildlife were sampled – and amphibians and reptiles (herpetofauna), and birds (avifauna) including wading birds, songbirds, waterfowl. The avifauna of Lake Okeechobee has been studied extensively in recent years, although the focus has largely been centered on wading birds. Very little information exists on the diversity and distribution of herpetofauna in Lake Okeechobee beyond anecdote, so this study not only serves as a basal inventory of amphibians and reptiles of the Lake Okeechobee western littoral zone, but as baseline information that may be useful when considering species responses to, or tolerance of, various hydroperiods associated with alternative lake regulation schedules.

# II. DESCRIPTION OF STUDY AREA

## A. Physical Conditions

### 1. Topography

The Lake Okeechobee bottom is relatively flat in the center with a moderate rise up to the north and west sides. Elevations range from around 3 meter (m) (10 feet (ft) NGVD) in the Moonshine Bay area to around 4.6 m (15 ft NGVD) in the Indian Prairie marsh (Richardson and Hamouda 1995). The Lake Okeechobee littoral zone currently occupies approximately 400 $km^2$ (154 square miles) (21%) of the Lake's total area, and its width varies from 0.8 km to 14.5 km (1/2 mile to 9 miles wide) (Richardson & Hamouda 1995).

### 2. Hydrology

Lake Okeechobee receives water primarily from rainfall and from the Kissimmee River, Taylor Creek, and Fisheating Creek basins (James et al. 1995). Water is released from the Lake through the West Palm Beach, Hillsboro, North New River, Miami, St. Lucie, and Caloosahatchee River canals. The primary inflow of water to the study area (the littoral zone) is from Fisheating Creek, rainfall, and pelagic water, while the sole outfall within the study area is the Caloosahatchee River canal (Figure 1). A significant amount of water is lost to evapotranspiration each year due to the Lake's large surface area to volume ratio.

The water table or non-artesian aquifer, located throughout the Lake Okeechobee area, is usually within one meter (3.28 ft) of the land surface and extends to about 100 m (330 ft) below land surface (bls) (Schroeder et al. 1954). The flow of this groundwater typically follows a north to south gradient. The major artesian aquifer underlying this region is the Floridan Aquifer, which occurs from about 300 m (1,000 ft) bls to bedrock.

Regulation of Lake Okeechobee has occurred since the late 19$^{th}$ century, when a canal was dug connecting Lake Okeechobee with the Caloosahatchee River for the purpose of lowering the water level in the Lake to aid in drainage of the

Everglades for agricultural purposes (SFWMD 1998). Additional canals were dug in the early 20th century for to provide additional drainage for the Everglades' agricultural areas. Following the hurricanes of 1926 and 1928, in which wind tides rose to a destructive 27 feet (mean sea level (msl)), a comprehensive levee system became a major need, spawning the construction of the Herbert Hoover Dike (HHD) system and numerous control gates around Lake Okeechobee by the Corps. These control structures, located at various points around the Lake, are used collectively to regulate lake stages within specified ranges based on a variety of performance criteria. All inflows and outflows, with the exception of Fisheating Creek, are regulated by control structures.

## B. Socioeconomic Conditions

The primary land use surrounding Lake Okeechobee is agriculture. Sugar cane plantations, cattle ranching, ornamental nurseries, vegetable production, and citrus make up the majority of agricultural land use in this area. Farmland occupies from 50 to 76% of the total land area within the counties that surround Lake Okeechobee (Glades, Hendry, Martin, Okeechobee, and Palm Beach Counties) (Purdum 1994).

Other common land uses in the Lake Okeechobee region are those frequently associated with agriculture. Sugar cane refineries, produce packaging and shipping plants, and other support activities constitute a major land use along with direct agriculture (Purdum 1994). Florida is one of the leading agricultural states in the nation, and as recently as 1993, was eighth in cash receipts totaling nearly $6 billion. The State leads the nation in citrus production, as well as in many vegetable crops, particularly those grown in the winter. About 90% of the fresh vegetables grown each year in the U.S. in January and February come from Florida. On an annual basis, Florida is second in the production of all vegetables. In 1993, the State accounted for 15.2% of the nation's total vegetable production. Florida was second in the nation for sales in horticulture, with sales of more than $1 billion annually, and floriculture, with annual sales of more than one-half billion dollars (Florida Department of Agriculture and Consumer Services 1991 and 1993). Production in the Everglades Agricultural Area has made Florida the leading sugarcane producer in the nation. This small area accounts for more than one-half the value of sugarcane grown in the United States.

The historic modifications in and around Lake Okeechobee, particularly the levee system, referred to as the HHD delineates the current boundaries of the Lake. The HHD allows water levels to be regulated to a degree that would not be attainable without a dike system.

Sport fishing is another major activity on the Lake. There are several major sportfishing tournaments held on Lake Okeechobee annually, which bring revenues to the marinas, fishing guides, hotels, and support industries along the Lake. It should be noted that the Lake supports several commercial finfishing endeavors, including fisheries for bullhead catfish (*Ictalurus* spp.), gizzard shad (*Dorosoma cepedianum*), striped mullet (*Mugil cephalus*), and gar (*Lepisosteus* spp.).

There are also commercial fisheries on the Lake that harvest the American alligator and the Florida soft shell turtle (Moler and Berish, 1995). Alligators are harvested from the Lake population to supplement the stock in alligator farming operations. Soft shell turtles are harvested by commercial fishermen, with the majority of the harvest shipped to Japan, or sold locally, primarily to the Miccosukee Native American tribe (Moler, pers. comm. 1998).

Heavy waterfowl utilization of the Lake attracts tourists and recreational enthusiasts (i.e., hunters). Common waterfowl species include ring-necked duck (*Aythya collaris*), American wigeon (*Anas americana*), Northern pintail (*Anas acuta*), green-winged teal (*Anas crecca*), lesser scaup (*Aythya affinis*), and Florida duck (*Anas fulvigula*).

The Lake has also been a historic tourist destination for purely aesthetic reasons. Airboat rides and guided fishing outings are popular tourist activities on the Lake. The planned extension of the Florida National Scenic Trail and creation of the Lake Okeechobee Scenic Trail have encouraged the recent trend toward eco-tourism.

## C. Biological Conditions

### 1. Vegetation

The study area lies within the western littoral zone and marsh of Lake Okeechobee and extends from the rim canal adjacent to the HHD, east to the littoral zone/lake interface, south to the Mayaca Cut, and north to Fisheating Bay (Figure 1).

The habitat types for this study were selected by the Corps, in conjunction with the SFWMD and the Florida Game and Fresh Water Fish Commission (FGFWFC), and include spikerush (*Eleocharis* sp.), torpedograss (*Panicum repens*), cattail (*Typha* spp.), and hydrilla (*Hydrilla verticillata*). Hydrilla was eliminated from herpetofaunal sampling due to the impracticality of utilizing standard sampling techniques.

The littoral zone plant community is composed of a mosaic of emergent, submergent, and floating plant species. Richardson and Harris (1995) refer to a total of 30 distinguishable community types in their digital cover map study.

Emergent vegetation within the littoral zone is dominated by herbaceous species such as cattail, spikerush, and torpedograss. Other emergent vegetation observed includes: bulrush (*Scirpus californicus*), rush (*Scirpus cubensis*), ludwigia (*Ludwigia leptocarpa*), sawgrass (*Cladium jamaicense*), pickerelweed (*Pontederia cordata*), duck potato (*Sagittaria* spp.), beakrush (*Beakrush tracyi*), melaleuca (*Melaleuca quinquenervia*), wild rice (*Zizania aquatica*), arrowhead (*Sagittaria latifolia*), button bush (*Cephalanthus occidentalis*), sand cordgrass (*Spartina bakeri*), fuirena (*Fuirena scirpoidea*), primrose willow (*Ludwigia peruviana*), southern cutgrass (*Leersia hexandra*), maidencane (*Panicum hemitomon*), white-vine (*Sarcostemma clausum*), dogfennel (*Eupatorium capillifolium*), mikania (*Mikania scandens*), and Carolina willow (*Salix caroliniana*).

The submergent vegetation is composed almost entirely of hydrilla, pondweed (*Potamogeton illinoensis*), and tape-grass (*Vallisneria americana*).

The floating component of the study area consists of water hyacinth (*Eichhornia crassipes*), water lettuce (*Pistia stratiotes*), bladderwort (*Utricularia* sp.), and duckweed (*Lemna* sp.). The rooted, floating leaved-vegetation consists of lotus lily (*Nelumbo lutea*), fragrant water lily (*Nymphaea odorata* and *N. mexicana*), and coinwort (*Hydrocotyle umbellata*).

## 2. Wildlife Resources

The study area includes a wide variety of habitat opportunities for wildlife, including wading and migratory birds, many mammals, amphibians, and reptiles, as well as other species such as crayfish, prawns, apple snails, and aquatic insects. The U.S. Fish and Wildlife Service has designated 19 species of mammals, 14 species of birds, 11 species of reptiles, 3 species of fish, and 3 species of invertebrates as threatened or endangered in South Florida, many of which may occur within the Lake. There are also State listed species present within the Lake, including several of the wading bird species such as the little blue heron (*Egretta caerulea*), sandhill crane (*Grus canadensis*), white ibis (*Eudocimus albus*), and limpkin (*Armamus guarauna*), which are not on the federal list.

**a. Herpetofauna:** According to range maps presented in Conant and Collins (1991), herpetofaunal diversity should be quite high in the study area. Previously studied species on Lake Okeechobee include the American alligator (*Alligator mississippiensis*) (L. Hord, pers. comm.) and the Florida soft-shelled turtle (*Apalone ferox*) (Moler, pers. comm.). Currently, no published inventories are available on the diversity of herpetofauna inhabiting the western littoral zone of Lake Okeechobee. However, this study has produced a database that includes many of the expected species. Species such as the greater siren (*Siren lacertina*) were sampled in high numbers along with the Florida green water snake (*Nerodia floridana*) and the banded water snake (*Nerodia fasciata*). Additional common species observed include pig frog (*Rana grylio*), two-toed amphiuma (*Amphiuma means*), and Southern leopard frog (*Rana utricularia*). The American alligator is the only listed species of reptile recorded in the study area. There are no listed species of amphibians currently known to utilize the study area.

Of additional interest is the possibility of colonization of exotic amphibians and reptiles within Lake Okeechobee. Several reports from local residents include sightings of non-native species of lizards, such as the green iguana (*Iguana iguana*), the spiny-tailed iguana (*Ctenosaura pectinata*), and the brown basilisk (*Basiliscus vittatus*). It has not yet been confirmed that these species are, in fact, breeding populations, but it is under investigation by Dr. Brian Butterfield of Freed-Hardeman University. Established populations of such species might be harmful to native herpetofauna.

**b. Avifauna:** The western littoral zone provides foraging opportunities and nesting habitat for a wide range of avifauna. Documented in this study, as well as previous studies (Smith and Collopy 1995; David 1994), are birds including the endangered wood stork (*Mycteria americana*), the Federal and State endangered snail kite (*Rostrhamus sociabilis*), great blue heron (*Ardea herodias*), white ibis, pied-billed grebe (*Podilymbus podiceps*), great egret (*Casmerodius albus*), snowy egret (*Egretta thula*), little blue heron, tricolor heron (*E. tricolor*), and common gallinule (*Gallinula chloropus*).

Other birds observed utilizing the littoral zone include the threatened bald eagle (*Haliaeetus leucocephalus*), brown pelican (*Pelecanus occidentalis*), double-crested cormorant (*Phalacrocorax auritus*), and anhinga (*Anhinga anhinga*).

**c. Mammals:** Lake Okeechobee also provides resources for mammalian species. The Okeechobee Waterway, a designated channel that lies along the perimeter of the lake, provides habitat for the endangered West Indian manatee (*Trichechus manatus latirostris*). Additionally, river otters (*Lutra canadensis*), bobcats (*Felis rufus*), and the Florida water rat (*Neofiber alleni*) were observed within the study area.

**d. Fish:** The study area is home to a large number of fish species, many of which are valued as commercial and sportfish. In the areas being sampled as part of the wildlife utilization study, numerous small fish species, including Cyprinodontids such as the golden topminnow (*Fundulus chrysotus*), the least killifish (*Heterandria formosa*), and the Florida flagfish (*Jordanella floridae*) were sampled and are known to be important food resources for wading birds, amphibians, and reptiles.

Additionally, Warren et al. (1995) revealed that numerous sportfish occur in the littoral zone. The largemouth bass (*Micropterus salmoides*) is one of the most popular gamefish in the State of Florida, and is a major predator of small fish, amphibians, and reptiles. Additionally, bluegill (*Lepomis macrochirus*) and redear sunfish (*L. microlophus*) are sportfish found in the littoral zone.

**e. Macroinvertebrates:** Macroinvertebrates in the western littoral zone provides yet another vital component to the food web. Species encountered during sampling events of the wildlife utilization study include the apple snail (*Pomacea paludosa*), an important food resource of the Everglades snail kite, crayfish (*Procambarus* spp.), grass shrimp (*Paleomonetus paludosus*), and Dytiscid beetles (Dytiscidae), among others.

## III. MATERIALS AND METHODS

The Corps, the SFWMD, and the FGFWFC first determined community types to be sampled prior to a reconnaissance trip conducted on March 1997. Sampling site selection was a cooperative effort between the Corps, the SFWMD, and representatives of L&A. Initial reconnaissance occurred in March 1997, during which time the study area was surveyed via helicopter and airboat. During this survey, potential sites were identified. Suitable sampling areas were marked on 1:12,000 color infrared aerial photographs. The selected sampling sites represented as homogeneous or representative sites as possible for each vegetative community. In some areas, the sample sites have become more heterogeneous over time. In particular, the wet torpedograss sampling areas changed during the course of this study such that they became a mixture of torpedograss, spikerush, water lily, and other plants.

Within the selected areas, the location of bird transects and herpetofaunal arrays were randomly chosen by L&A personnel. The locations of the bird transects were placed near the herpetofaunal arrays.

Eight, approximately week-long, sampling events were conducted during this study: May 1997, July-August 1997, October-November 1997, January 1998, March 1998, June 1998, September 1998, and November 1998. Each day of each sampling event, the time, date, Differential Global Positioning System (DGPS) coordinates, an estimation of percent vegetative cover, air and water temperature, water depth, color, and clarity, wind speed and direction, and overall weather conditions were recorded. Percent vegetative cover was visually estimated for the areal coverage of vegetation and/or open water by randomly placing $1m^2$ quadrats within each community type near each sampling point. Additionally, lake stage data and rainfall data were supplied by the Corps' lockmaster at the S-77 lock in Moore Haven.

The locations of all sampling areas were recorded using a Magellan Meridian XL portable GPS unit. Beginning with the July-August 1997 sampling event, a differential beacon receiver was utilized which, coupled with the GPS unit, provides readings that are within two to ten meters of accuracy. The corrected DGPS coordinates are provided in Tables 1a and 1b.

The approximate locations of sampling areas were as follows: two spikerush sites were located within the Moonshine Bay area (general vicinity of MH-24,000); another two spikerush sites were located off the east side of the Old Moore Haven Canal approximately 0.75 mile (1.2 km) north of the rim canal; the hydrilla sites were located within the Fisheating Bay area; the cattail sites are located between the Monkey Box and Moonshine Bay (specifically on the south side of the airboat canal which runs due east from the Monkey Box); and the torpedograss sites were located just east of the Old Moore Haven Canal. Representative photographs of the sampling sites are included as Appendix A. Maps of the sampling locations are included in Appendix B.

A geographic information system (GIS) was created using ArcInfo and the coordinates of the sampling stations. The coordinates were converted from WGS84 to North American Datum of 1927 per the Corps' request. This GIS contains coverages representing all of the sampling sites. These coverages were later converted into ArcView files. A table containing the field data collected at each point for each sampling event was created using dBase 5.5 and later imported into ArcView files to facilitate interpretation of data. A legend for the points created in ArcView files is provided in Tables 1a and 1b. These data were then overlaid onto the vegetation map provided by the Corps and produced by the SFWMD. Color plates showing the physical locations of sampling sites were generated (Appendix B). This map was developed by the SFWMD to document existing vegetative communities with the Lake.

## A. Herpetofaunal Sampling Methodology

Sampling methodology for herpetofauna followed general procedures as outlined in Dalrymple (1996). In addition, coordination with Dr. Mike Dorcas, a postdoctoral fellow at the Savannah River Ecology Laboratory (SREL), Paul Moler, a herpetologist with the FGFWFC, and Kevin Enge (FGFWFC) was conducted to fine-tune sampling methodologies utilized in this study.

For sampling of herpetofauna within the Lake Okeechobee littoral zone, four Y-shaped drift fences (with each arm measuring 15.24m) were constructed and placed within each of the three cover types (spikerush, torpedograss, and cattail). Two cover types - spikerush and torpedograss - were split into two hydrologic subtypes due to elevational differences. These habitats were separated into wet and dry subcomponents into which two drift fences were placed. After the July 1997 sampling event, all dry sites became and remained inundated for the remainder of the study. Four drift fences were placed within the cattail community.

Turtle trapping arrays utilized consisted of three 36-inch diameter hoops constructed of 2 inch mesh nylon netting. Turtle traps were connected by 25 foot leads to each arm of the drift fences (three per fence) or were located near the drift fence, where hydrologic conditions permitted. The traps were baited with pieces of cantaloupe and canned tuna. This methodology follows the recommendation of Paul Moler of the FGFWFC (pers. comm.).

During both the May 1997 and July-August 1997 sampling events, the torpedograss habitats lacked the depth of water necessary for placement of turtle traps. During the March 1998 sampling event, water levels were too high for placement of turtle traps. The traps could not be relocated because the investigators could not locate, within a reasonable amount of time, any areas that contained both the correct water depth and vegetative cover types for trap placement.

During the January 1998 and March 1998 sampling events, water levels at most drift fences were above the tops of the fences. For this reason, half of the funnel traps at each drift fence were modified in an attempt to minimize trapping mortality often resulting from high water conditions. Modified traps consisted of cylindrical tubes placed vertically against the fences with two funnels at the top and two funnels at the bottom of the trap. The tube or body of the traps extended above the water line, ensuring that animals trapped would have the opportunity to breathe. It is not known what effect the modified traps had on the trapping efficiency of the arrays.

During the January 1998 sampling event, the standard and modified traps were set along the submerged drift fences in the same manner as had been done in prior sampling events. However, the even higher water levels encountered during the March 1998 sampling event made it extremely difficult to attach the traps to the drift fences properly and securely. For this reason, at sampling sites in which water depth exceeded six feet, the funnel traps were hung from any vegetation as close to the drift fence as possible that could support the weight of the trap. The same number of traps (9) were set at each drift fence in each sampling event.

Due to poor weather conditions during the October/November 1997 sampling event, drift fences in the deep water areas (cattail and spikerush) and the turtle trapping sites (cattail and spikerush) were not sampled.

Sampling occurred for five continuous days for each event. For all sampling events, all traps were checked at least once a day between 0800 hours and 2000 hours. However, since our study was based on an aquatic environment, there was a need for more frequent checking efforts to prevent overcrowding and extensive mortality of animals in the traps.

Although fish, macroinvertebrates, and mammals were not being specifically sampled as a part of this study, field observations of these animal groups were noted and documented when present as incidental occurrences during sampling for birds and herpetofauna. However, the methodology utilized for the sampling of herpetofauna or avifauna was not considered adequate for the sampling of fish, macroinvertebrates, or mammals. Records of incidentally trapped fauna are presented in Appendix C.

## B. Avifaunal Sampling Methodology

Most bird surveys conducted on Lake Okeechobee have been done via aircraft (Johnson and Montalbano 1984; Zaffke 1984; Smith and Collopy 1995; Smith, Richardson and

Collopy 1995) and have focused on wading birds. Aerial surveys are unable to accurately record non-wading birds such as shorebirds and song birds because of the visibility and auditory constraints of sampling from an aircraft. Since the scope of this study was to evaluate wading and non-wading bird habitat/water level relationships, ground surveys of avifauna were conducted.

The survey methodology used in this study was modified from Dalrymple (1996) and Krebs (1985). Birds were sampled along 300m line transects. Sampling occurred for four continuous days for each sampling event. Each transect was surveyed during the morning from approximately 0600 hours to 1200 hours. An arbitrary sampling point was established in each site. Using a range finder, a second sampling point was established in an arbitrary direction 150 meters from the initial point. At each sampling point, a 2" X 8' (Schedule 40) PVC pole were driven into the ground to mark the location for subsequent sampling periods. Two tangent circles (each with a 75 meter radius) were established at each sampling point thereby making a 300 meters transect. At each sampling point, auditory and visual observations were recorded for a period of three minutes. When birds were recorded based on vocalizations, they were distinguished from one another by their individual songs or calls. When identical songs or calls were given, individuals were distinguished by the cadence and direction of the song or call. The potential for double counting of a bird only occurred if it moved within the period of observation. Such movements, if observed, were noted.

Because of the differential visibility between habitats, all observed species were recorded as either occurring within the 75 meter radius or outside the 75 meter radius from the sampling point. This differentiation was originally made so that equal area comparisons could be made between habitat types for the observations within 75 meters.

When large numbers of birds were encountered, as in the October/November 1997 sampling event, observations were completed by dividing the group of birds in question into quadrants and counting the birds within each quadrant. The numbers were broken down by species with total numbers counted for each species.

In this study, four separate habitats were sampled: cattail, hydrilla, spikerush, and torpedograss. The survey sites chosen were the best representative areas available for each of the habitats. Three of the habitats were initially sub-characterized based on hydrological conditions: hydrilla (floating and submerged), spikerush (wet and dry), and torpedograss (wet and dry). The division of hydrilla was based on the initial survey of the area being sampled, while the designation of "wet" and "dry" torpedograss and spikerush was predetermined before the study began. Hydrilla was characterized by areas where the hydrilla was floating and areas where the hydrilla was submerged. Over the course of the study all the hydrilla sites fluctuated between floating and submerged and the initial designation did not accurately reflect the subsequent characteristics of the sites. The "dry" torpedograss and spikerush communities were not inundated at the time of the first sampling event, but for subsequent sampling events they were inundated yet still had lower water depths than the associated wet sites. Over the course of the study the "wet" torpedograss was reclassified as a wet mixed grass habitat due to increased vegetational heterogeneity at the site. Therefore, the different sites are now called: hydrilla (4 transects), cattail (4 transects), "dry" torpedograss (2 transects), wet mixed grass (2 transects), "dry" spikerush (2 transects), "wet" spikerush (2 transects).

Sampling access to sites varied depending on water depth. Some transects were reached exclusively by airboat while others were at times reachable by foot or by propeller boats. Regardless of the mode of transportation, any birds that were flushed as researchers were approaching also were recorded. Individuals were not recorded if they were seen using another habitat type within the specific habitat being sampled (e.g., dense stand of cattails within an expanse of spikerush). In addition, birds flying over the habitat enroute to another area outside the area being sampled were not recorded.

Sampling was uniform in all habitat types except in cattails where, due to the density of the vegetation, researchers were physically unable to access the dense stands by airboat, boat, or on foot. As a result, the sampling points were established near the edge of extensive cattail stands. Birds were only recorded if they were within the cattails. For this particular habitat, placing transects within the periphery was the only practical methodology due the constraints previously outlined. Coincidentally, this methodology was implemented in a previous study by Roth (1997). However, the fact that sampling did occur on the edge of the cattail habitat does increase uncertainty due to possible "edge effect" bias. This possible bias may manifest itself as increased avian diversity and abundance arising from greater habitat diversity.

During the March 1998 sampling event, there were high winds during most of the sampling days. These winds caused the open water to be too rough and unsafe for the boats, particularly in the hydrilla. Because of this, two of the original hydrilla transects were not sampled. However, a more sheltered location was inspected and two new transects were selected within this area which were representative of the original transects.

## C. Data Analysis

### 1. General Considerations

The data for herpetofaunal and avifaunal surveys were divided into taxonomic and/or functional groups for analysis. The herpetofauna data were divided into amphibians and reptiles. Other incidentally trapped taxa included macroinvertebrates, mammals, and fish. All bird species in the data set were characterized as a South Florida resident or migrant utilizing the FGFWFC's *Checklist of Florida's Birds* as a reference. This was done in an attempt to look at potential resident and migrant bird group differences.

Birds were also divided into functional groupings outlined in Drew and Schomer (1984) (Table 2).

For the avifauna data analysis, all observations, whether they occurred within or outside the 75 meter radius, were added together. This was done because most of the bird observations were recorded beyond the 75 meter radius. Therefore, the combined observations better represented any potential habitat and/or water level relationships. Because of this, however, comparisons of avifauna between habitats based on total abundance was not conducted. Only relative abundance was used for comparisons between habitat types. In contrast, total abundance was used for "within habitat" comparison since the sampling areas were equivalent.

**2. Analyses**

**a. Analyses of Variance (ANOVA)** : The herpetofaunal and avifaunal abundance data were analyzed using the same Analysis of Variance (ANOVA) model (SAS 6.12). The model relates the observed abundance to the following factors: Habitat, Transect, Water Depth (cm), and Season

The Transect factor was nested within the Habitat factor, since the transects represented a type of replicate sampling within each habitat. Because the same transects were sampled each time, transects were treated as a fixed effect in the model. Both Season and Water Depth interacted with Habitat, enabling a statistical evaluation of the effects of these two factors within each habitat.

The response variable, abundance, was transformed using the square-root transform, commonly applied to count data in order to ensure more homogeneous variability. Parametric models were estimated first using all data, and then after eliminating outliers, defined for this analysis as those observations having studentized residuals (from the first model) exceeding 2.0. A non-parametric model was also estimated, utilizing the ranks of the abundance observations as the response. Its results were generally supportive of the parametric model results.

A similar parametric modeling process was used to evaluate the relative abundance of birds. The Water Depth effect was not included in this analysis because this analysis was conducted to look at the habitat relationships. No transformation was applied to the relative abundance response. Outliers were trimmed using the same procedure, and a non-parametric analysis of ranks was again performed. These models enabled the comparison of mean relative abundance across habitat.

Significant results from the parametric model are reported that meet the following criteria: a) the overall p-value for the ANOVA model was less than

0.05; b) the effect or relationship being tested had a p-value less than 0.05; and c) the coefficient or specific result of interest had a p-value less than 0.05.

b. **Cluster Analysis:** Cluster analyses were performed to measure the similarity (and dissimilarity) of habitat types based on relative abundance of bird groups and herpetofauna (Figures 2 through 5). Relative abundance was used in place of abundance because of the differences in the sampling visibility between habitat types for birds and because of the small number of captures of herpetofauna. In addition, cluster analyses were performed to measure the similarity between bird groups and between herpetofauna based on habitat utilization. Separate analyses were performed for resident bird groups. Habitat types were separated into "wet" and "dry" for torpedograss and spikerush, as well as submerged and floating for hydrilla. Similarities of sampling units were calculated using the Bray-Curtis Index of Percent Dissimilarity (Ludwig and Reynolds 1988) with percent similarity equal to the dissimilarity value subtracted from 1.0. Group clusters were joined using an un-weighted pair-group arithmetic means (UPGAM) amalgamation method. Clustering was demonstrated graphically in the form of dendograms (tree diagrams). In the results, the similarity indices are described as percentages and represent the relative similarity of groups compared to the other groups (e.g. If Habitat 1 and Habitat 2 are 99% similar then these two habitats are more similar to each other than they are to other habitats based on the data used to assess their similarity). Cluster analysis is a qualitative/descriptive analysis that does not produce a statistic that can be interpreted as "significant" or "not significant". It evaluates whether habitats or groups are similar.

c. **Index of Dispersion Test**: To determine if herpetofaunal species showed patterns in their habitat usage, an Index of Dispersion (I) was calculated. The variance in individual species mean abundance was divided by the mean abundance of a sample within the habitat where a species was recorded (Krebs, 1989). The test statistic for the index was a chi square ($X^2$), where degrees of freedom (df) equal number of habitats minus 1. Interpretations were based upon a two-way test, in which the null hypothesis was that the distribution was random and was accepted if:

$$X^2_{0.975} < \text{Observed} > X^2_{0.025}$$

Significant differences less than 0.025 were interpreted as "uniform", and greater than 0.975 were interpreted as "clumped". Because of the differences in sampling areas between habitats, the Index of Dispersion Test was not appropriate for the bird data.

## IV. AMBIENT CONDITIONS

## A. General Weather

The May 1997 and July-August 1997 sampling events followed a normal weather pattern for Lake Okeechobee (C. Hanlon, pers. comm. 1998). However, the October-November 1997, January 1998, and March 1998 sampling events occurred during periods of above normal rainfall for the region (although little was recorded during the sampling events at the Moore Haven Lock) (Table 3). Due to severe drought conditions experienced throughout most of Florida between April and August 1998, the water levels recorded at the Lake Okeechobee study area dropped by approximately one meter (3.3 feet) between the March 1998 and June 1998 sampling events.

Temperatures fluctuated seasonally, as expected (Graph 1). Only two sampling events (March 1998 and June 1998) had temperatures significantly different from the norm. A late season cold front occurred in March 1998, and a heat wave blanketed the area with near record high temperatures in June 1998.

## B. Hydrology

Water levels varied within habitat types and among arrays and transects (Tables 4 though 7, Graphs 2 through 5). However, similar trends were observed for all sample sites. The minimum depth recorded was during the May 1997 sampling event when there was little or no standing water recorded in the "dry" spikerush community. The maximum depth was recorded during the March 1998 sampling event when water depth exceeded 200 cm (6.5 feet) in the cattail community.

The lake stage was influenced by numerous factors throughout the study, including unusually high rainfall throughout the region from December 1997 through March 1998 and unusually low rainfall from March 1998 through August 1998. This resulted in a lake stage that, at times, had been well above or well below the regulation schedule. These changes may also have contributed to changes that occurred in the composition of vegetation within the sampling locations during the course of the study.

## C. Vegetation

Vegetation sampling for this study was conducted to assess the habitats being sampled and to document possible changes in vegetative composition.

### 1. Spikerush

**a. Conditions at Herpetofaunal Arrays:** Two drift fences were placed in areas adjacent to the Old Moore Haven Canal and two were placed in areas within Moonshine Bay. The arrays placed near the canal were without standing water at the beginning of the study and were representative of a spikerush community. The arrays near Moonshine Bay were in relatively undisturbed areas and contained little torpedograss. However, these communities, while they appear to be composed uniformly of spikerush from a distance, are quite diverse as well. While overall diversity in spikerush communities sampled is quite uniform (Table 8a), it appears that the species assemblages in the vicinity of the Old Moore Haven Canal are different from those in the undisturbed Moonshine Bay area. However, spikerush is still the dominant vegetation at both sites.

**b. Conditions at Avifaunal Transects:** Since bird transects were set in the same general areas as the drift fences for the spikerush community, similar statements can be made for the diversity of the vegetation (Table 8b). There were small differences in species composition between bird transects and drift fences.

## 2. Cattail

**a. Conditions at Herpetofaunal Arrays:** The herpetofaunal arrays were placed as far back from the canal as possible (Table 9a). Diversity is generally low, and cattail maintained dominance throughout the study despite periods of high water levels. Species assemblages changed little between sampling events. Species such as bladderworts and duckweed also were present in this community, although they occupied a different stratum and were present in lower densities.

**b. Conditions at Avifaunal Transects:** Vegetation within bird transects were sometimes less homogenous than the habitat associated with drift fence sampling areas because of the inability to traverse deeply within cattail communities (Table 9b). Species such as bladderwort, water lettuce, and fragrant waterlily also were present in higher numbers. However, visually, the areas sampled were similar to the drift fence areas.

## 3. Hydrilla

### a. Conditions at Avifaunal Transects

Hydrilla was a difficult community to survey visually. At the beginning of the study, the hydrilla community had areas of floating and areas of submerged hydrilla, both of which were very dense to the bottom. The hydrilla community changed over time in species composition (Table 10), but this change may have been caused by seasonality and hydrology.

### 4. Torpedograss

**a. Conditions at Herpetofaunal Arrays**: Two torpedograss sites (four drift fences) were located adjacent to the Old Moore Haven Canal. One site was higher in elevation than the other by approximately 5 to 10 cm, which resulted in measurable hydrologic differences between the sites. The "drier" site (DFDT1 and DFDT2) had similar species assemblages to its lower elevation counterpart. However, the wetter site (DFWT1 and DFWT4) appeared to undergo colonization of new species, for example, spikerush and water lilies, during the study (Table 11a). The higher elevation site had higher densities of torpedograss than the lower site. Both sites appeared as high density torpedograss flats at the time of drift fence installation.

**b. Conditions at Avifaunal Transects**: Bird transects were placed in the same general areas in which drift fences were placed. Visually, the areas appeared the same, and overall, species diversity differed slightly (Table 11b).

# V. RESULTS OF WILDLIFE SURVEYS

## A. Herpetofauna

### 1. General Trends

The Florida green water snake and the greater siren comprised the most frequently captured herpetofauna for the spikerush community type (Table 12a). Species richness was highest during the October 1997 sampling event, but overall richness fluctuated only slightly. Only during the January 1998 and March 1998 sampling events were there no herpetofauna captured in the spikerush community.

Species abundance was highest during the October 1997 sampling event, when large numbers of Florida green water snakes and greater sirens were captured. Species composition varied among sampling events. However, no frogs or skinks were trapped after the October 1997 sampling event.

Overall herpetofaunal richness and abundance was very low in the cattail community for all sampling events except for the July 1997 event (Table 12b). Nearly all events yielded two or fewer species and seven or fewer individuals. Cattail arrays were not sampled during the October 1997 sampling event. Sampling did occur in January 1998 and March 1998, with no herpetofauna being captured. Only four herpetofaunal species were captured in the three subsequent sampling events.

The torpedograss community had a slightly higher species richness compared with the other habitats sampled (Table 12c). In general, species richness decreased as water depths increased. Abundance sharply increased during the October 1997 sampling event, which was due to the high numbers of greater sirens, Florida green water snakes, and pig frogs captured.

## 2. Habitat Relationships

a. **ANOVA Parametric Analysis**: ANOVA parametric analyses were performed on herpetofauna to determine if there were any statistical correlations between water depths, herpetofaunal captures, or seasonality with the studied habitat types.

i. **Water Depth Relationships within Habitat Types**: The statistical parametric analysis revealed that a potentially significant inverse relationship exists between amphibian captures and water depth for the spikerush sites (Table 12a). This potentially significant result was found only in the parametric model. The same result was found in dry torpedograss, however, the p-value fell just short of the 95% confidence level at 94.64%. The relationship for both habitat types was that as water depth increased, the number of amphibians captured decreased.

Results obtained from the analysis of reptile data were revealing as well although they were not significant at a 95% confidence level. When evaluated at a 90% confidence level, the ANOVA parametric analysis exhibited an inverse relationship between captures and water depth for the wet spikerush sites. As with the amphibians, reptile captures decreased as water depths increased.

ii. **Capture Relationships Between Different Habitat Types**: There were no significant or potentially significant results for the parametric or the non-parametric ANOVA's analyses of relationships between the different habitat types and the number of herpetofauna captures.

iii. **Seasonal Relationships within Habitat Types**: A potentially significant relationship between the quantity of captures during the wet (May-September) or dry (October-April) seasons and any of the habitat types was found with the parametric model for amphibians. Amphibian captures were greater in dry spikerush and dry torpedograss during the dry season than during the wet season.

b. **Cluster Analysis**: Cluster analysis of herpetofauna revealed that the torpedograss sites were very similar (79%) to each other based on the relative abundance of herpetofauna trapped (Figures 6 and 7). In addition, the dry spikerush showed a similarity of 75% to the torpedograss sites. The wet spikerush was very dissimilar with all other sites with only a 24% similarity.

Cluster analysis based on habitat associations also was conducted for herpetofauna. The analysis revealed that some herpetofauna formed distinct faunal assemblages. Species that are represented by less than three trapped individuals were not included in this analysis because they could lead to incorrect conclusions due to their small sample size. The most similar of herpetofauna, with a similarity of habitat of 81%, were pig frogs and Florida brown water snakes (*Nerodia taxispilota*). These species are more closely associated with spikerush habitat. Another group with similarities above 70% were southern leopard frogs and greater sirens (78%) in torpedograss. A larger assemblage of herpetofauna with a similarity of 67% included southern cricket frogs, southern leopard frogs, Florida green water snakes, greater sirens, and two-toed amphiumas. This assemblage is most associated with torpedograss.

c. **Index of Dispersion Test**: During the eight sampling events, 15 different herpetofauna species were trapped within the three habitats studied. An Index of Dispersion Test was conducted to assess possible correlations between species and habitats. The test revealed which species showed clumped, random or uniform distributions within the three habitat types. No herpetofaunal species exhibited clumped distributions. The greater siren, southern cricket frog and the peninsular newt showed random distributions. All other species showed uniform distributions.

### B. Avifauna

Avifauna observed during the study are represented in Tables 13a through 16b.

#### 1. ANOVA Habitat Relationships

The ANOVA analysis showed some bird groups exhibited a close affinity (confidence >95%) with certain habitats while other groups, such as aerial feeding birds and short legged wading birds, did not show a significant relationships (Table 17).

**Arboreal Birds:** There were no significant differences between the relative abundance of arboreal birds in cattail, "dry" spikerush, and "dry" torpedograss. Cattails did have a significantly greater relative abundance than the wet mixed grass habitat. Cattail, "dry" spikerush, "dry" torpedograss, and wet mixed grass all had greater relative abundance of arboreal birds than hydrilla and "wet" spikerush.

**Aerial Searching Birds:** There were no significant differences between "dry" spikerush, hydrilla, "wet" spikerush, and wet mixed grass habitats. However, these habitats had greater relative abundance than cattail and "dry" torpedograss.

**Floating and Diving Birds:** Floating and diving birds comprised a larger component of the bird population in hydrilla than all other habitats. Cattail and "wet" spikerush were similar in relative abundance. The relative abundance of floating and diving birds in "dry" torpedograss and wet mixed grass communities was less than in the cattail and "wet" spikerush habitats. "Dry" spikerush habitats had a significantly lower relative abundance of these birds when compared to all other habitat types.

**Raptors and Vultures:** "Dry" spikerush had significantly higher relative abundance for raptors and vultures as compared to all other habitats. There were no significant differences between the relative abundance of cattail, "dry" torpedograss, hydrilla, "wet" spikerush, and wet mixed grass habitats.

**Shorebirds:** "Dry" torpedograss had the highest shorebird relative abundance as compared to the other habitat types. Wet mixed grass sites had significantly greater relative abundance as compared to cattail, "dry" spikerush, hydrilla, and "wet" spikerush for which there was no significant difference in relative abundance.

**Surface Feeding Ducks:** There was no significant difference between the relative abundance of surface feeding ducks in "dry" spikerush and "wet" spikerush. Both habitat types had greater relative abundance than cattail, "dry" torpedograss, hydrilla, and wet mixed grass for which there were no significant differences in relative abundance.

**Long Legged Wading Birds:** Wet mixed grass habitats had significantly greater relative abundance for long legged wading birds than the rest of the habitat types. "Wet" spikerush had the second highest long legged wading bird relative abundance and it was significantly greater than cattail, "dry" spikerush, "dry" torpedograss, and hydrilla habitats for which there were no significant differences in relative abundance.

## 2. Cluster Analysis Habitat Relationships

Cluster analyses generally supported the ANOVA results (Figures 2 through 5). The cluster analysis of habitat type differences based on bird group associations of all resident and migrant bird groups showed that the hydrilla habitats were very similar (96%), but were very distinct from the other habitats. Cattail and wet mixed grass were also similar (75%) based on bird group relative abundance. There was not a significant difference between the rest of the habitats.

The analysis for resident bird groups also showed that cattail and wet mixed grass were very similar to each other (92%) based on bird group utilization. "Dry" spikerush and torpedograss (79%) were similar based on resident birds. The hydrilla habitats were also similar (92%). "Wet" spikerush was more similar to the hydrilla habitats.
The cluster analysis of bird group differences based on habitat associations showed that, when both residents and migrants were evaluated together, there was little dissimilarity between the bird groups. All were very similar (79%). Surface floating ducks, raptors and vultures, aerial flying birds, and arboreal birds also form a group at 81%. Wading birds, shorebirds, floating and diving birds, and aerial searching birds form another group (90%). When the migrants are not included in the cluster analysis, only the short legged wading birds and the floating and diving birds had a high degree of similarity (86%). Aerial searching birds and long legged wading birds formed a weak group with short legged wading birds and floating and diving birds (65%). Arboreal birds and raptors and vultures formed a distinct group from the other groups but only had a similarity index of 45%.

### 3. Water Depth and Seasonal Relationships

The ANOVA analysis showed significant water level relationships, both positive and negative, and seasonal relationships for different bird groups within certain habitat types. Two groups, arboreal and aerial searching birds, showed no water depth or seasonal relationships (Table 18).

**All Groups:** As water depths increased, bird observations significantly increased in cattail. This significant trend was evident when the data were run for all birds, resident birds, and migrant birds. There was an opposite effect for bird observations in hydrilla. As water depths increased, bird observations significantly decreased for all birds, resident birds, and migrant birds.

In hydrilla habitats, bird abundance was significantly greater during the dry season as compared to the wet season for all birds, resident birds, and migrant birds. In cattail habitats, bird abundance was significantly greater during the wet season for resident birds.

**Aerial Feeding Birds:** Aerial feeding bird observations significantly increased as water depths increased in cattail, hydrilla, "dry" torpedograss, and the wet mixed grass habitats. There were no significant differences between seasonal abundance in any of the habitats for aerial feeding birds.

**Floating and Diving Birds:** There was a significant negative relationship between floating and diving bird abundance and water depth in hydrilla. As water depths increased, floating and diving bird numbers decreased. Floating and diving bird abundance was significantly greater during the dry season in hydrilla.

**Raptors and Vultures:** There were no significant trends for raptors and vultures as water depths changed during the study period in any of the habitats. Season did have a significant effect on raptors and vultures in "dry" torpedograss, dry spikerush, and "wet" spikerush. They were more numerous during the wet season.

**Shorebirds:** There were no significant trends for shorebirds in any of the habitats as water depths changed during the study period. The dry season had greater shorebird abundance than the wet season in hydrilla.

**Surface Feeding Ducks:** There were no significant trends for surface feeding ducks in any of the habitats as water depths fluctuated during the study period. Surface feeding ducks were more numerous within hydrilla during the dry season than during the wet season.

**Long Legged Wading Birds:** There was a significant inverse relationship between increasing water depths and long legged wading bird abundance in hydrilla and "wet" spikerush. In addition, long legged wading birds were significantly more abundant during the dry season than the wet season in hydrilla.

**Short Legged Wading Birds:** There were no significant trends for short legged wading birds in any of the habitats as water depths changed during the study period. Short legged wading birds were more abundant during the wet season in cattail habitats, but exhibited the opposite relationship in hydrilla, where short legged wading birds were more abundant during the dry season.

## VI. DISCUSSION

The Wildlife Survey and Habitat Utilization Study for Lake Okeechobee's western littoral zone was conducted to further the knowledge base of the impact of the range of lake stages on herpetofaunal and avifaunal populations. This information may assist managers in determining a lake regulation schedule that optimizes ecological benefits with minimum or no adverse impact to other study's project purposes, including water supply, flood control, recreation, and navigation.

The goal of this study was to gather baseline herpetological and avian data to attempt to determine any possible relationships between water depth and habitat utilization by those species. During the timespan of this study, observable changes have occurred in the vegetative composition at some of the sampling sites. This and other possible sources of statistical variation must be kept in mind when evaluating the results of this study. These variations would include high water level sampling and associated decreased sampling efficacy, trap modifications to cope with high water conditions, cold weather sampling (such as during the March 1998 sampling event), unusual rainfall patterns, relatively small sample size due to a survey of only one and one-half years, and low capture quantities

## A. Herpetofauna

### 1. Habitat Relationships

**a. General Habitat Relationships**: Three habitat types were sampled for herpetofauna: cattail, spikerush (wet and dry), and torpedograss (wet and dry). The wet and dry differentiation originally referred to inundated versus uninundated areas within the respective community types. After the first sampling event, all sites became inundated; therefore, the distinction is now used to differentiate between lower and higher elevation spikerush or torpedograss sites. This distinction is important when evaluating possible relationships between habitat and/or water depth and herpetofauna species.

Parametric statistical analysis of the data revealed a significant inverse relationship between water depth and herpetofauna captures. Although there may be a potential statistical correlation between them, other factors not within the scope of this study may have contributed to low herpetofauna captures during sampling events when the water levels were highest. The sampling events with the highest recorded water level occurred in January and March of 1998. During these events, air and water temperatures were the coldest recorded in the study. Because herpetofauna are cold blooded, their behavior and especially motility are negatively affected by cold temperatures. In addition, the high water levels compromised the design effectiveness of the trapping arrays. These factors, in addition to possible seasonal behavioral differences, may have had a significant effect on trapping success even though herpetofauna richness and abundance may not have changed at all.

Another significant relationship that was exposed by parametric statistical analysis was the greater number of captures of amphibians in dry spikerush and torpedograss sites during the "dry" season (October 1997 through April 1998). However, this relationship may not be as significant as the analysis reveals since during that time the highest water levels during the study were recorded. In other words, that particular "dry" season was wetter than the "wet" seasons before or after it. This may have disrupted normal seasonal migrations if any did exist. Thus, conclusions regarding relationships between herpetofauna habitat utilization and seasonality are thereby influenced.

Cluster analysis revealed the presence of several habitat and herpetofaunal assemblages. It should be noted that these results are sometimes based on species with low number of captures. For this reason, these results must be viewed with caution.

### 2. Specific Habitat Relationships

**a. Cattail Habitat**: Cattails proved a very difficult habitat to sample. This was the case not only with regard to traversing the dense vegetation, but also in keeping the traps free of debris. Many times the traps were full of debris to such an extent as to render them almost useless. Debris intrusion was most evident during the last three sampling events when a large percentage of decomposing plant matter was observed within the drift fences. It is not know why the problem seemed to intensify in the Summer and Fall of 1998. It is possible that the rapidly dropping water levels may have been a contributing factor although this potential relationship is not understood at this time. Although difficult to sample, this habitat type did yield seven different herpetofaunal species, two of which (greater siren and two-toed amphiuma) were found in high numbers until cold weather, high water, and/or dense suspended dead organic matter likely reduced the trapping efficiency in this habitat.

**b. Spikerush Habitat:** Spikerush was the most hydrologically different habitat of all the habitats sampled. The water depths for the wet and dry sites differed by approximately 70 cm. This difference is evident when conducting cluster analysis of the habitat types by relative abundance of herpetofauna. The hydrologic difference was so significant that the dry spikerush site was more similar in relative abundance of herpetofauna trapped to all other habitat sites than to the wet spikerush. In addition, the dry spikerush site is not as pristine as its wet counterpart. Numerous dead melaleuca stumps litter the area where the dry sites are located. The difference in hydrology coupled with the different site histories render comparison of these habitats tenuous at best. In addition, the low water levels experienced during the first two sampling events allowed species such as the Southeastern five-lined skink to have access to these areas which would not be accessible to them for the remaining sampling events due to higher water levels.

**c. Torpedograss Habitat**: Torpedograss is considered an exotic invasive plant species in Florida. However, when found in less dense monocultures, this habitat type appears to support densities of herpetofauna comparable to those found in native vegetation. It should be noted that the areas of torpedograss sampled are not representative of the dense and extensive areas of torpedograss found in more remote areas of the littoral zone.

Based on cluster analysis, it appears that dry spikerush, dry torpedograss, and wet torpedograss share some attributes, such as structure, water depth, etc., that may be perceived as comparable by herpetofauna and, thus, support a similar assemblage of herpetofaunal species. This suggests that habitat conversion from spikerush to torpedograss in shallow areas does not appear to have deleterious effects on herpetofauna habitat utilization. However, this is contrary to what others have observed in dense monocultures of torpedograss, where it has been reported that these areas are more sterile than their spikerush counterparts (Chuck Hanlon, pers. comm. 1998). The fact that neither the wet nor dry torpedograss sites sampled exhibited the extreme densities of more remote unsampled torpedograss sites is significant in understanding differences, or lack thereof, between abundance of herpetofauna captured in spikerush and torpedograss during this study. Future research is needed to assess what impacts dense torpedograss monocultures have on herpetofaunal species.

## B. Avifauna

In this study, seventy-seven (77) different species of birds were observed using the littoral zone of Lake Okeechobee. American coots (*Fulica americana*), red-winged blackbirds (*Agelaius phoeniceus*), common gallinules, and tree swallows (*Tachycineta bicolor*) were found in the highest densities in this study. Other species such as the great egret, anhinga, boat-tailed grackles (*Quiscalus major*), and common yellowthroat (*Geothlypis trichas*) were consistently observed. Hoyer and Canfield (1994) surveyed Florida lakes and found certain species occurring at the highest densities especially the American coot and red-winged blackbird. Other than studies done on wading birds in Lake Okeechobee and in the Everglades, there is little quantitative data available for the relationships between other bird groups and habitat types (Smith et al. 1995, Breininger and Smith 1990, Gawlik and Rocque 1998, Kushlan and Kushlan 1977, Brown and Dinsmore 1986, Fredrickson and Reid 1986). Researchers reported that other species such as the great egret, anhinga, turkey vulture (*Cathartes aura*), snail kite, common gallinule, tree swallow, common yellowthroat, red-winged blackbird, and boat-tailed grackle were commonly found in marshes of the Everglades (Gawlik and Rocque 1998). These species were all observed in the marshes of Lake Okeechobee's littoral zone during this study.

The results of eighteen months of sampling the avifaunal communities of Lake Okeechobee's littoral zone showed that water level changes do significantly affect some of the avifauna of Lake Okeechobee within certain habitats. Specifically there is a negative relationship with various bird groups in hydrilla and "wet" spikerush and a positive relationship with various bird groups in cattail habitats. In addition, aerial searching birds showed a positive relationship with increasing water levels in a number of habitats.

The highest numbers of birds were recorded within the hydrilla habitat, up to 9,000 individuals and 33 different species during one sampling event. The cluster analysis revealed that the hydrilla habitat was very unique and dissimilar from all the other habitats in the study. During the different sampling periods the hydrilla habitat drastically changed in vegetative cover as water levels rose. The floating vegetation used for walking and foraging by many of the observed species, such as American coots and common gallinules, disappeared with increasing water levels. The ANOVA analysis revealed that as a group floating and diving birds, for which coots and gallinules were the dominant species, decreased as water levels rose in hydrilla habitats. As a group, floating and diving birds also favored hydrilla habitats over the other habitats based on their relative abundance and had the highest abundance of any bird group. This use of hydrilla by floating and diving birds is supported by the literature. Hydrilla supports high densities of small fish and grass shrimp (McIvor and Smith 1992) and serves as a direct vegetative food source for some species such as the American coots (Johnson and Montalbano 1984).

Hydrilla also benefits other birds, such as wading birds (Smith et al. 1995), when it "tops out" (i.e., when hydrilla reaches the surface of the water) and makes deep water accessible. In addition to floating and diving birds, long legged wading birds also significantly decreased with increasing water depth in hydrilla. Great blue herons and great egrets were the two long legged wading bird species that were recorded and affected. Other species and groups such as the snowy egrets and shorebirds also appeared to be affected although the analysis did not find significant relationships. Snowy egrets have been characterized to feed in open shallow areas (Jenni 1969), as have shorebirds (Skagen and Knopf 1994). Floating mats of the hydrilla habitat represented open shallow areas for feeding. Observers noticed a drop in shorebird abundance during high water levels. Shorebird diversity and abundance has been shown to decline after rising water levels covered feeding areas (Taylor et al. 1993, Taylor and Trost 1992, Hand et al. 1991).

Increasing water levels did not negatively affect all bird groups or all bird species in hydrilla. Aerial feeding birds increased in abundance as water levels rose in hydrilla. Although this result is statistically significant, its relationship may be a function of season rather than a water depth relationship. The tree swallow was the primary aerial feeding bird observed. It is a migrant and was only observed in fall and winter months, which during this study, was when water levels were high. It was also found to be positively correlated with increasing water levels in several other habitats including cattail, "dry" torpedograss, and wet mixed grass habitats. It was also only observed in these habitats during the Fall/Winter.

The other significant water level relationship found during this study is one that has been well documented by prior studies. Long legged wading bird abundance decreased as water depths increased in "wet" spikerush as well as in hydrilla. The long legged wading birds observed using this habitat were the great blue heron and the great egret.

The great egret was the most abundant and most consistently observed. Great blue herons and great egrets prefer to forage in 13-25 cm of water but can forage in water up to 50 cm (Smith et al. 1995). Their distributions are heavily influenced by water depth and are known to require narrow ranges in water depths (Kushlan et al. 1975, Kushlan 1976). Long legged wading bird abundance was greatest during the shallowest water depth periods. Wading birds in general have been studied extensively on Lake Okeechobee as well as throughout the palustrine and lacustrine systems in Florida (Custer and Osborne 1978, Kushlan et al. 1975, Kushlan 1976, Kushlan 1974, Kushlan 1993, Bancroft et al. 1994, Smith et al. 1995, Willard 1977, David 1994, David 1994 b, David 1994 c, Zaffke 1984, Ogden et al. 1980).

Increasing water depths had the opposite effect on avifauna in cattail habitats, as water levels rose bird abundance increased. Unlike in the hydrilla habitats, the increasing water depths did not cause the drastic structural changes in cattail. The tall emergent nature of cattail enabled it not be become flooded out and it remained intact for most birds to use regardless of increasing water level. The cattail habitats appeared to become more open as the denser dead material became inundated with water. The increased water depths opened up some areas in the cattail habitats making foraging easier for different bird groups. In addition, other researchers have also found that density and nesting success of marsh passerines is proportional to water depths below nests (Picman et al. 1993). Orians (1980) noted that the depth of water is important for decreasing nest predation for marsh passerines.

This study also looked at differences in seasonal abundances within habitat for the bird groups. This was done to better understand the relationship between season and water levels. Again hydrilla and cattail habitats show the most significant relationships. Bird abundance was greater during the dry season (November-April) in hydrilla for a number of different groups including migrants, residents, and all birds (residents and migrants). It is obvious that migrants would be positively correlated with the dry season months because this is the time period that corresponds with their migration. Floating and diving birds, as a group, had significantly greater abundance during the dry season in hydrilla. As stated previously, the most abundant floating and diving bird species in this study is the American coot, which is a migrant species. The American coot probably had a large affect on the analysis of the migrant birds as well as the analysis of "all birds" since their counts ranged upwards of eight to nine thousand during two of the wet season sampling periods in which they were recorded. Shorebirds were also significantly more abundant during the dry season. They were all characterized as migrants and are more abundant during the dry season (Stevenson and Anderson 1994).

Migration on a larger scale does not explain why the resident birds as a whole, short legged wading birds, and long legged wading birds were more abundant during the wet season in hydrilla. There may be regional migrations that occur during the year in South Florida or even within Lake Okeechobee. Zaffke (1984) found that there were distinct seasonal wading bird patterns on Lake Okeechobee with the fewest birds occurring during October-February. This study's findings did not support Zaffke's, but this study only observed bird populations for eighteen months while Zaffke (1984) analyzed accumulated data for over four years. Another important factor was the abnormal rainfall pattern in the region during the study. The Winter and early Spring had more rainfall than is normally recorded during this time period and this resulted in high water levels in Lake Okeechobee and in the region. This may or may not have affected wading bird seasonal patterns in the area but it can be hypothesized that as a result the increasing water depths throughout the region in palustrine and lacustrine habitats, birds may have been drawn to the floating hydrilla mats on the Lake.

Within the cattail habitat, resident birds and short legged wading birds increased in abundance during the wet season. The most abundant resident bird in cattail was the red-winged blackbird. The wet season (May-October) includes their breeding period. Other studies have found that red-winged blackbirds chose to nest in tall emergents habitats, such as cattail, especially in near open water edges (Albers 1978, Ozesmi and Mitsch 1997). In the field it was evident during this time of the year that red-winged blackbirds were setting up territories and defending them vigorously. The wet season is also the time when wading birds, in general, are also breeding and nesting on Lake Okeechobee (David 1994, Milleson 1987, Zaffke 1984). The most abundant short legged wading birds using cattail were the least bittern (*Ixobrychus exilis*) and the king rail (*Rallus elagans*). They tend to nest in tall emergent habitats such as cattail (Stevenson and Anderson, 1994).

Besides the water level and seasonal relationships a number of interesting habitat relationship were found. This study revealed that the cattail and wet mixed grass habitats in this study were similar based on bird community assemblages. These two habitat types were very different in vegetative species composition and structure and yet the analysis linked them based on their similar bird assemblages. There are a number of possible reasons for this relationship. The wet mixed grass sites were dominated by dense torpedograss that was intermixed with spikerush, patches of open water and small stands of sawgrass and woody vegetation. Birds that were seen solely using those stands of sawgrass and woody vegetation were not recorded unless they were seen utilizing the wet mixed grass sites also. Many species observed using both stands of spikerush and wet mixed grass areas were birds such as red-winged blackbirds, boat-tailed grackles, and tree swallows. Red-winged blackbirds are known to prefer tall erect vegetation and prefer open water edge habitats such as cattail or sawgrass (Albers 1978, Bancroft 1987). This potential overlap or "edge" effect may be one reason for the similarity. Since sampling occurred on the periphery of the cattail habitat it is difficult to say whether the bird assemblages found in the cattail sites represent the interior of cattail communities. Common gallinules were abundant in both the cattail and wet mixed grass sites. It is believed that common gallinules forage on floating vegetation (Bartedziej and Weymouth 1995) represented by wet mixed grass habitats. However, their relative abundance along the edges of the cattail community was consistently high.

This study also indicated that the "wet" spikerush sites were very different from the "dry" spikerush communities and were very dissimilar from the rest of the sites. The common gallinule was observed consistently in the "wet" spikerush as was the red-winged blackbird and snail kite. The red-winged blackbird tended to use the "wet" spikerush community secondarily by foraging away from cattail stands within the "wet" spikerush sites. Conversely, snail kites and common gallinules appeared to forage solely within the "wet" spikerush sites. The "dry" spikerush was structurally very distinct from the "wet" spikerush community and it was the site that had the least number of bird observations. The "dry" spikerush sites were the sites that were the closest to the Moore Haven Canal and had an extensive treated melaleuca forest adjacent to it. Most of the birds seen in this community were arboreal birds. However, in the "wet" spikerush sites, floating and diving birds were the most abundant and consistently observed.

Some specific bird groups/habitat relationships were found to be significant when the bird groups were analyzed to assess habitat preferences based on the relative abundance of bird groups within habitats. Arboreal birds were most strongly associated with cattail communities but were also found in "dry" spikerush, "dry" torpedograss, and wet mixed grass habitats. Arboreal birds such as red-winged blackbirds, boat-tailed grackles, common yellowthroats, and warblers need structure to perch on and forage from. Of the habitats, cattail provides the most extensive structure but within the other communities there were patches of cattail, sawgrass, or snags for birds to use as they utilized the different habitats and that may be the reason for arboreal birds to be associated with the other habitats.

Aerial searching birds favored areas where there was open water for them to scan the water's surface for prey items. These areas included hydrilla and "wet" spikerush habitats. These areas provided ample habitat for birds such as black terns (*Chlidonias niger*) and laughing gulls (*Larus atricilla*) to forage. The analysis also found that aerial searching birds showed preferences toward "dry" spikerush and wet mixed grass habitats. In these areas species such as belted kingfishers (*Cerle alcyon*) were observed.

Raptors and vultures also showed an affinity to the "dry" spikerush habitat. This may be attributable to the site's proximity to the treated melaleuca forest and to the Moore Haven canal. Species like red-shouldered hawks (*Buteo lineatus*) and ospreys (*Pandion haliaetus*) were consistently seen usually perched on dead snags in this habitat. Red-shouldered hawks are not usually associated with this type of marsh habitat and favor more wooded environments. Ospreys may find this habitat useful during higher water periods when larger fish are found in this type of habitat. However, they were likely observed here because they were foraging in and along the canal. The vultures may have been looking for "road" kills along the canal or simply for a perching spot further away from human disturbance.

Shorebirds relative abundance was highest in wet mixed grass habitats and in the "dry" torpedograss. Species such as greater yellowlegs were observed foraging in open water patches and in areas where the torpedograss was less dense. Shorebirds were also strongly associated with hydrilla habitats although the analysis did not reveal this because their relative abundance was much less in hydrilla than in other habitats. Using relative abundance does not reflect that their overall abundance in hydrilla may have been higher. Their association with hydrilla was dampened by the abundance of other species such as floating and diving birds that had very high abundance and thus reduced the effects of other groups such as shorebirds.

As previously stated, floating and diving birds were strongly associated with hydrilla but they were also more closely associated with cattail and "wet" spikerush than the "dry" torpedograss, wet mixed grass, and "dry" spikerush. This is because habitats such as hydrilla and cattail provide more macrophytic vegetation for which they depend.

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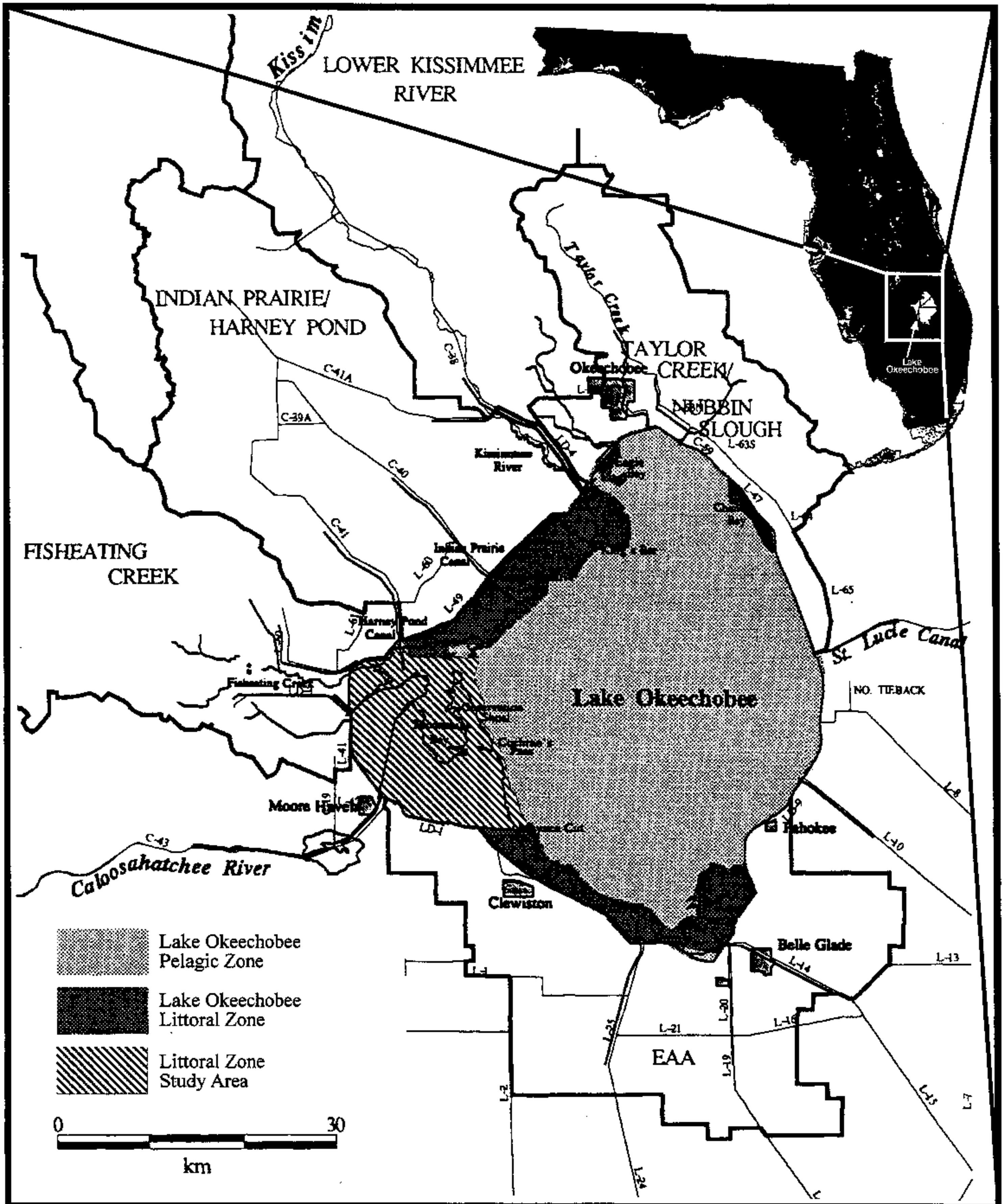
## FIGURES




| Lotspeich and Associates, Inc. ECOLOGICAL CONSULTANTS 422 West Fairbanks Avenue, Suite 201, Winter Park, FL 32789 (407) 740-8482 Fax 645-4305 e-Mail: Lotspeich@aol.com | Lake Okeechobee Wildlife Utilization Study | Project Location Map |
|---|---|---|
| File : OKE-LOC.CDR / Drawn By : JGS | Job No : 94056013.33 / Date : 6 October 1997 | North / Figure 1 |

## Figure 2: Cluster analysis of all avifaunal groups based on the similarity of habitat type associations observed along transects

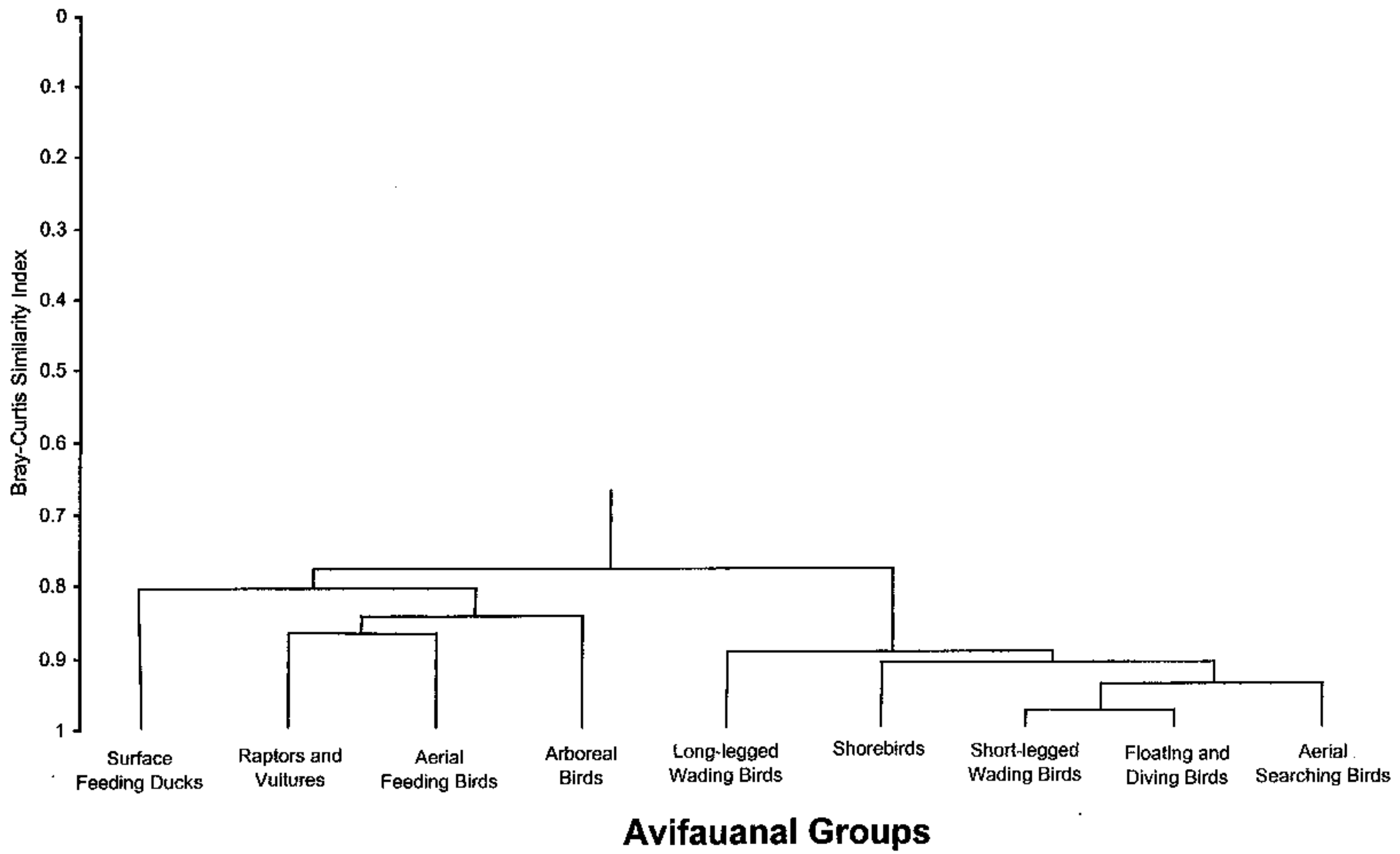


**Figure 3: Cluster analysis of resident avifaunal groups based on the similarity of habitat type associations observed along transects**

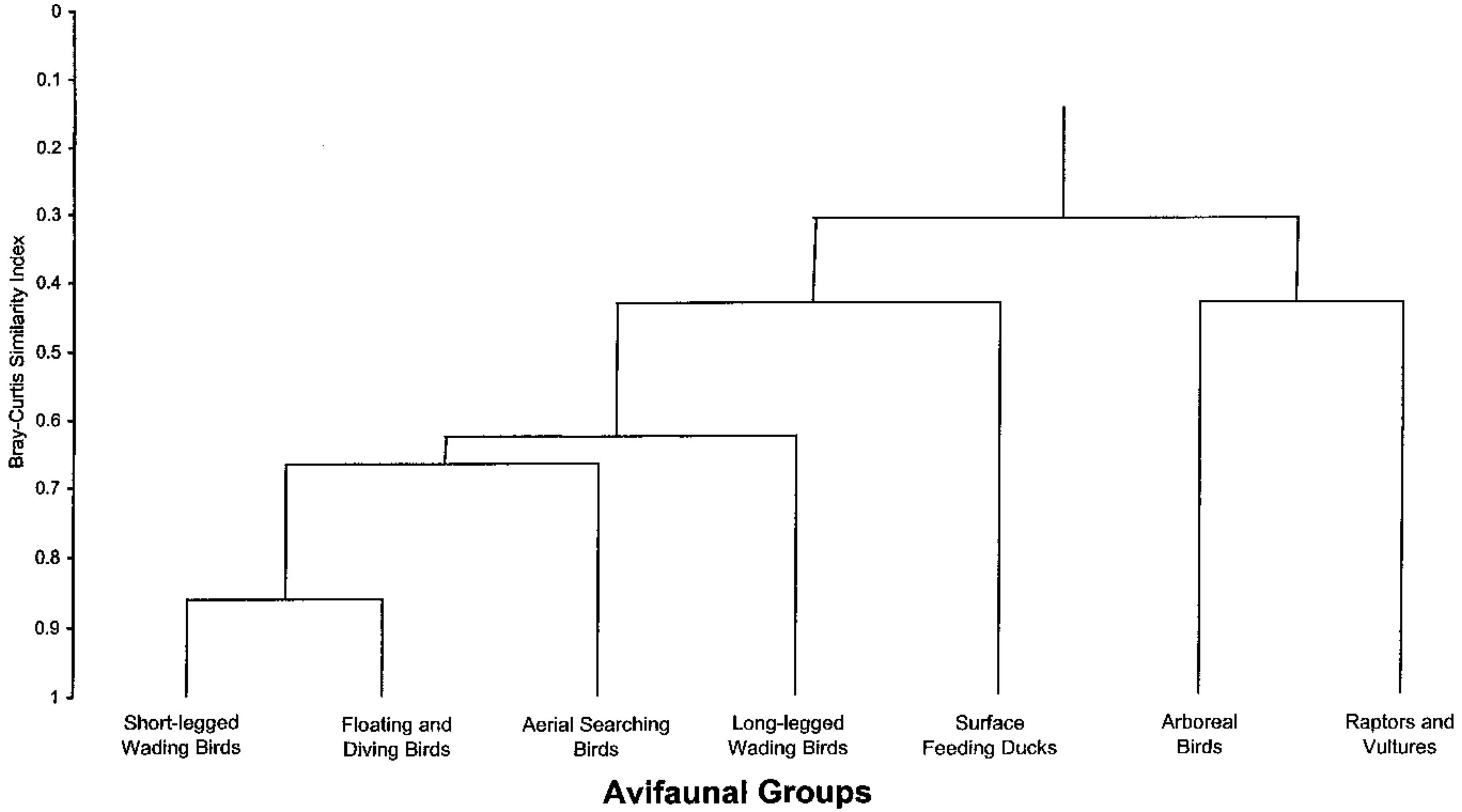


**Figure 4: Cluster analysis of habitat types based on the similarity of all avifaunal groups observed along transects**

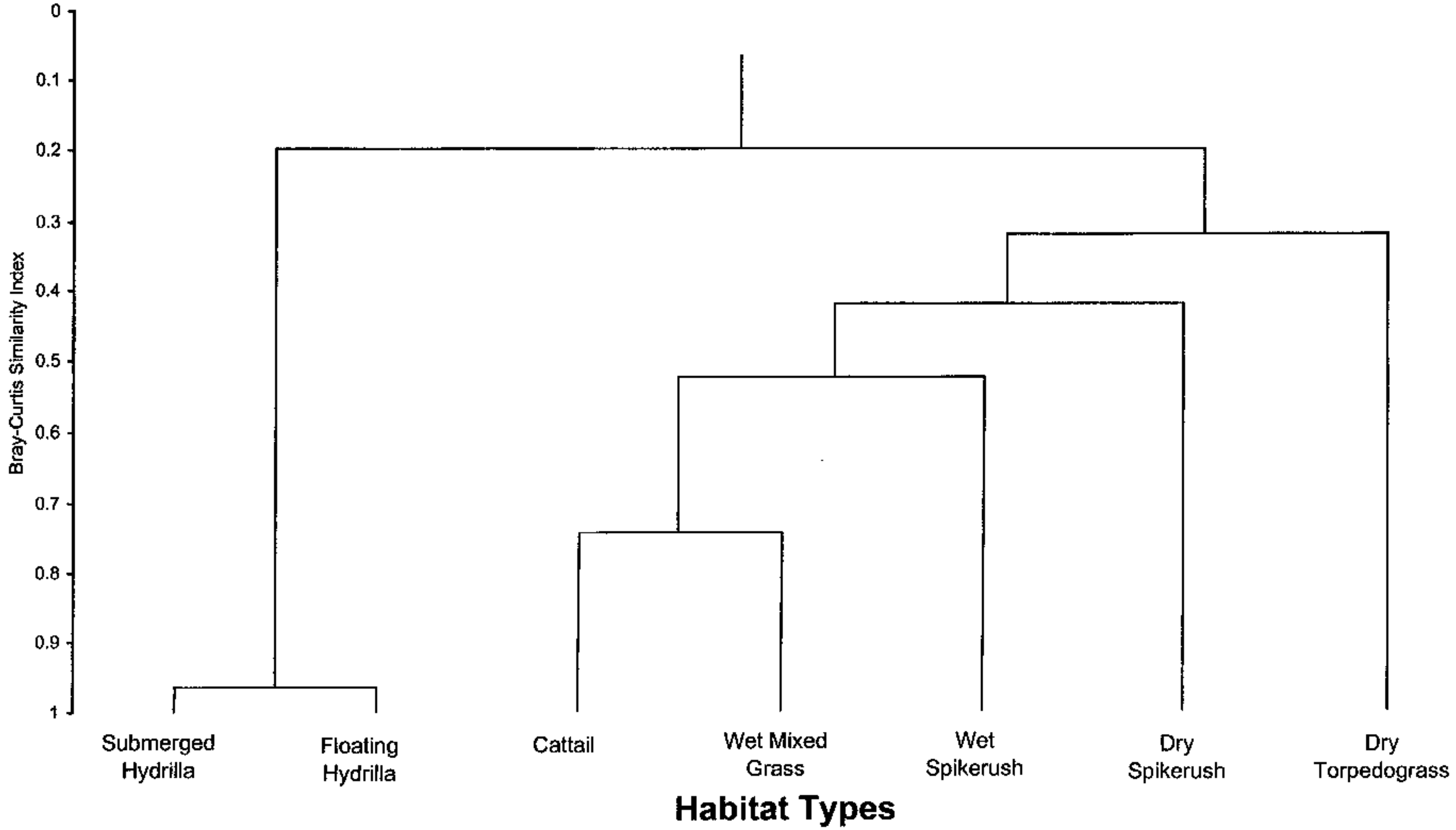
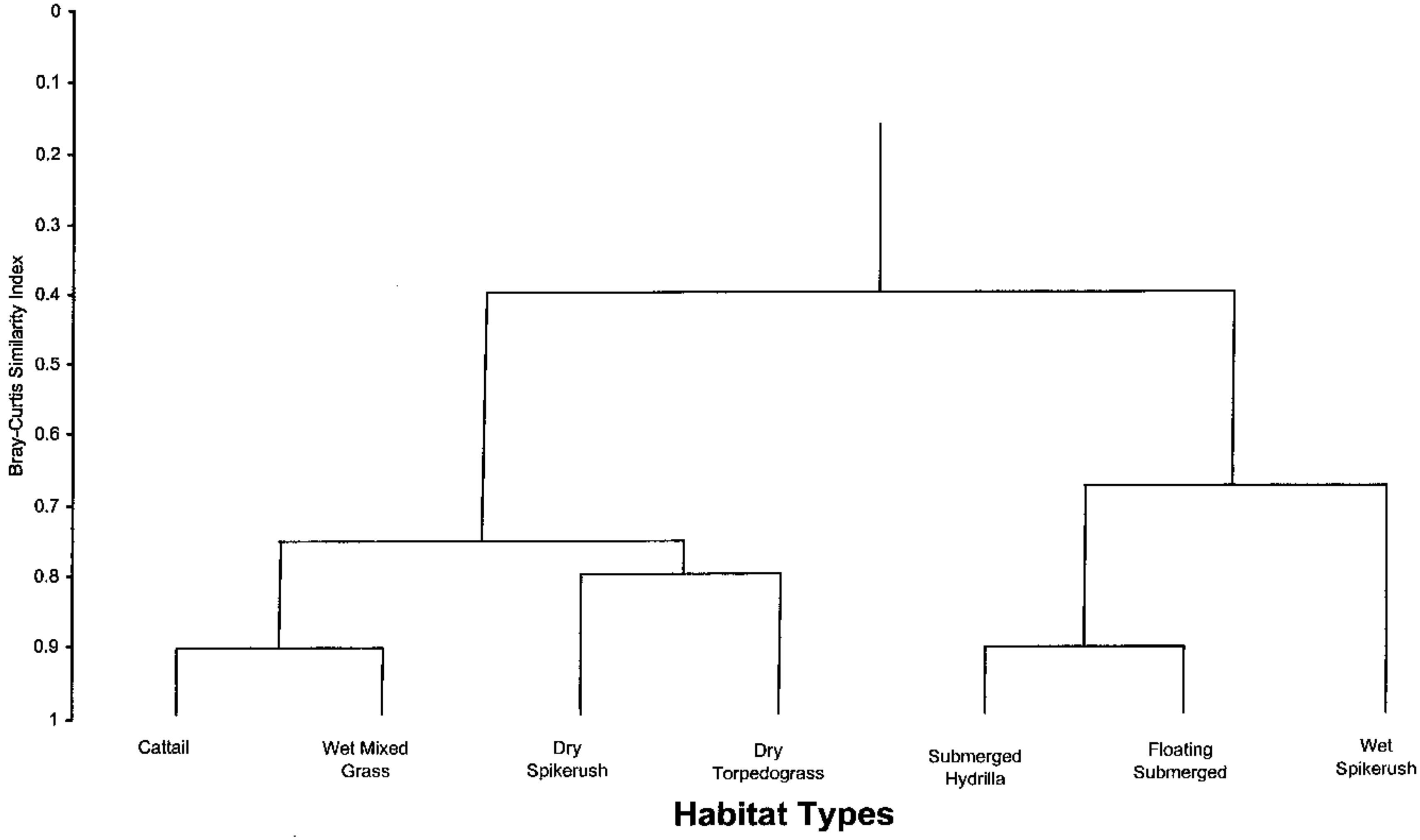
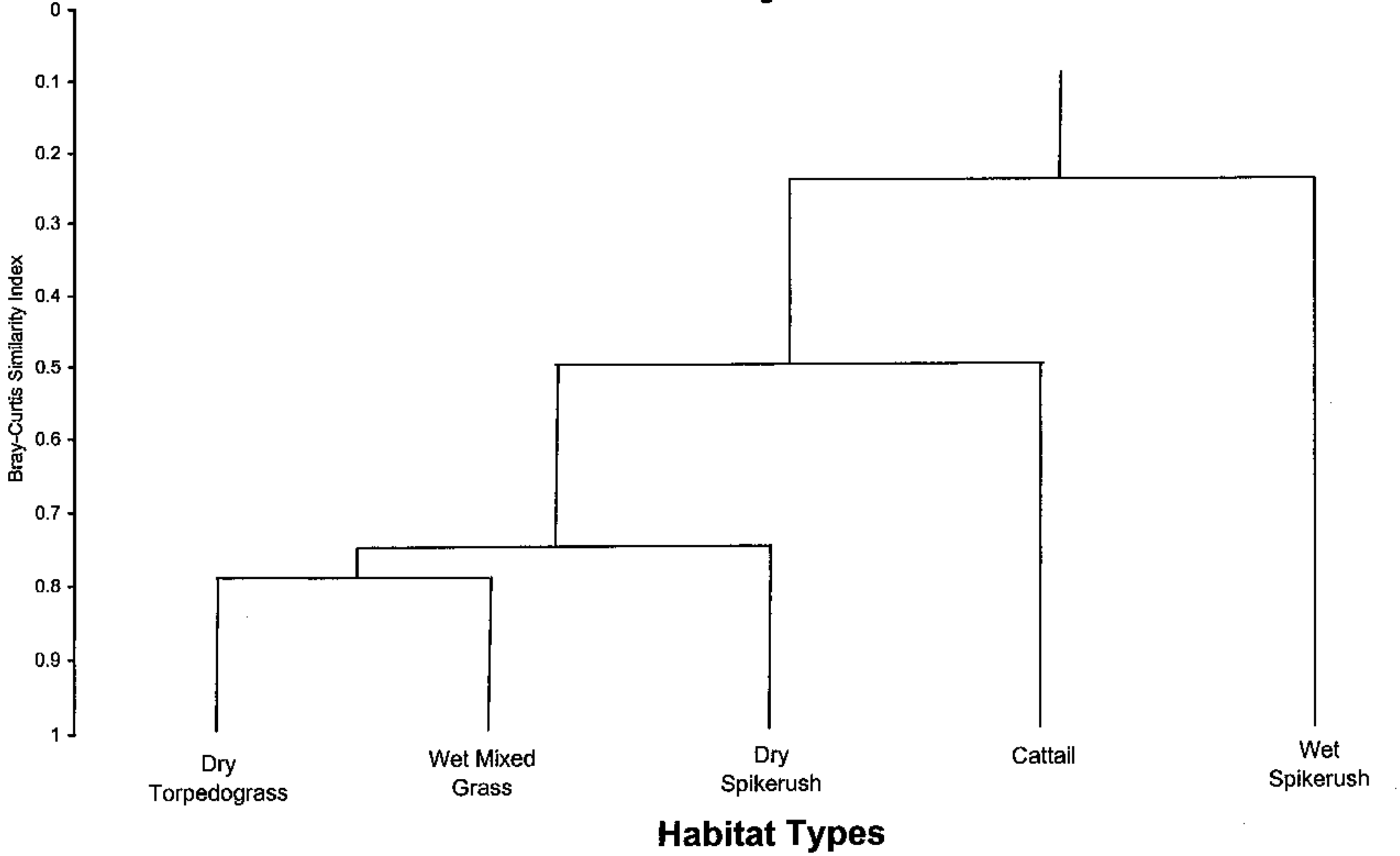


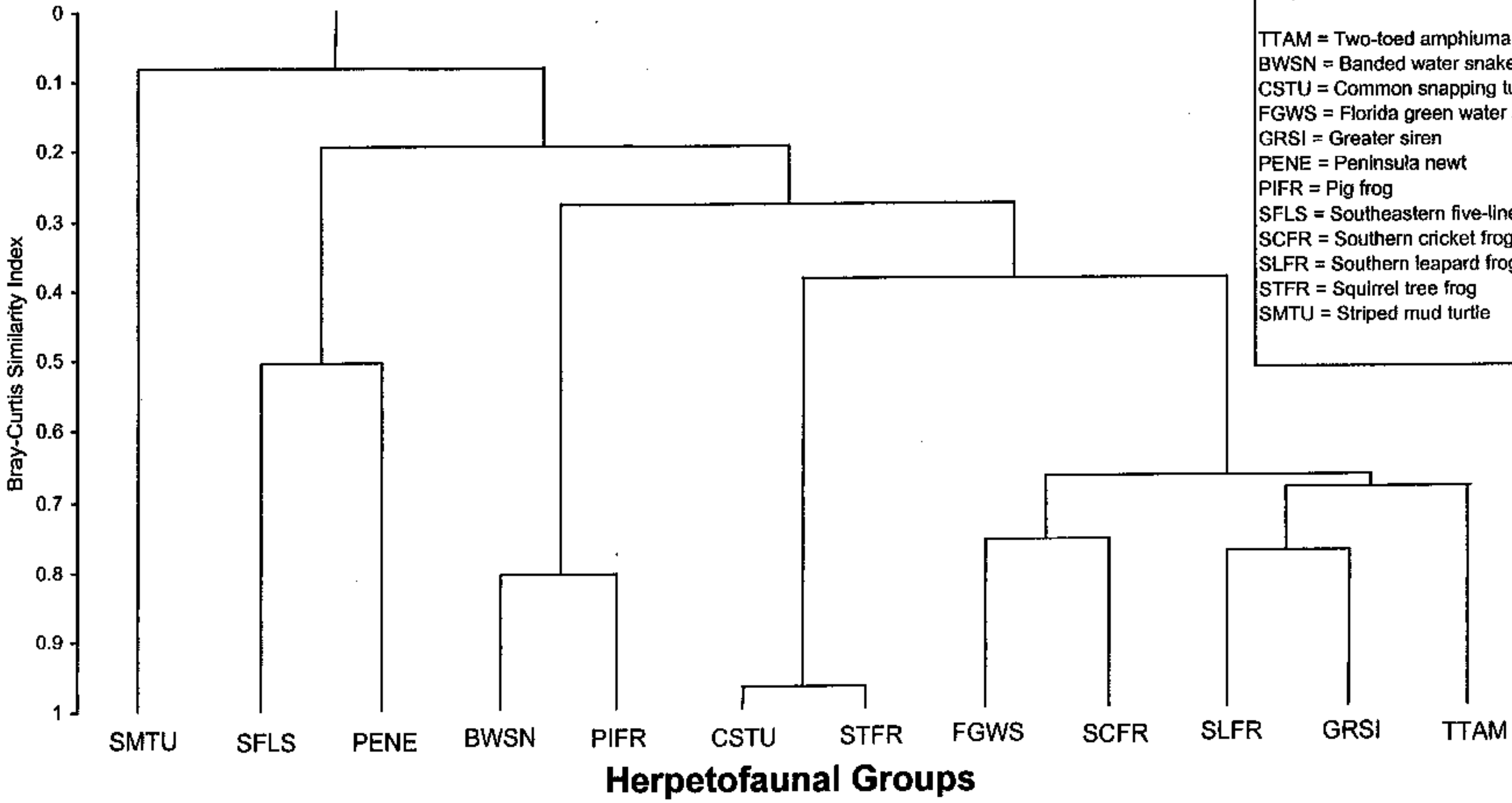
**Figure 5: Cluster analysis of habitat types based on the similarity of resident avifaunal groups observed along transects**



## Figure 6: Cluster analysis of habitat types based on the similarity of herpetofuana caught in trapping arrays



## Figure 7: Cluster analysis based on the similarity of habitat type associations for herpetofuana caught in trapping arrays




**Herpetofuanal Codes**

TTAM = Two-toed amphiuma
BWSN = Banded water snake
CSTU = Common snapping turtle
FGWS = Florida green water snake
GRSI = Greater siren
PENE = Peninsula newt
PIFR = Pig frog
SFLS = Southeastern five-lined skink
SCFR = Southern cricket frog
SLFR = Southern leapard frog
STFR = Squirrel tree frog
SMTU = Striped mud turtle

## TABLES

**Table 1a. DGPS Coordinates and Corresponding GIS Labels For Drift Fences (Coordinates are given in Degrees, Minutes, and Seconds)*.**

| | Drift Fences | |
|---|---|---|
| COVER TYPE | DGPS COORDINATES | GIS LABELS |
| Cattail (*Typha* sp.) | 26 55 56N 81 03 03W | DFC1 |
| Cattail (*Typha* sp.) | 26 55 56N 81 03 04W | DFC2 |
| Cattail (*Typha* sp.) | 26 55 38N 81 03 01W | DFC3 |
| Cattail (*Typha* sp.) | 26 55 34N 81 02 53W | DFC4 |
| Wet Spikerush (*Eleocharis* sp.) | 26 54 47N 81 02 39W | DFWE1 |
| Wet Spikerush (*Eleocharis* sp.) | 26 54 41N 81 02 38W | DFWE2 |
| Dry Spikerush (*Eleocharis* sp.) | 26 51 16N 81 03 60W | DFDE1 |
| Dry Spikerush (*Eleocharis* sp.) | 26 51 08N 81 03 24W | DFDE2 |
| Wet Torpedograss (*Panicum repens*) | 26 54 04N 81 04 22W | DFWT1 |
| Wet Torpedograss (*Panicum repens*) | 26 54 09N 81 04 14W | DFWT2 |
| Dry Torpedograss (*Panicum repens*) | 26 52 20N 81 04 58W | DFDT1 |
| Dry Torpedograss (*Panicum repens*) | 26 52 24N 81 04 42W | DFDT2 |

* Corrected values

**Table 1b. DGPS Coordinates and Corresponding GIS Labels For Bird Transects (Coordinates are given in Degrees, Minutes, and Seconds)*.**

| COVER TYPE | Point 1 | | Point 2 | |
|---|---|---|---|---|
| | DGPS COORDINATES | GIS LABELS | DGPS COORDINATES | GIS LABELS |
| Cattail (*Typha* sp.) | 26 56 12N 81 03 01W | CAT1 | 26 56 13N 81 03 06W | CAT1B |
| Cattail (*Typha* sp.) | 26 56 09N 80 47 07W | CAT2 | 26 55 59N 81 03 13W | CAT2B |
| Cattail (*Typha* sp.) | 26 55 28N 81 03 08W | CAT3 | 26 55 39N 81 03 02W | CAT3B |
| Cattail (*Typha* sp.) | 26 55 32N 81 02 48W | CAT4 | 26 55 33N 81 05 38W | CAT4B |
| Dry Spikerush (*Eleocharis* sp.) | 26 53 08N 81 04 07W | DE1 | 26 52 28N 81 04 36W | DE1B |
| Dry Spikerush (*Eleocharis* sp.) | 26 52 19N 81 04 48W | DE2 | 26 52 14N 81 04 46W | DE2B |
| Dry Torpedograss (*Panicum repens*) | 26 53 46N 81 04 20W | DT1 | 26 53 54N 81 04 25W | DT1B |
| Dry Torpedograss (*Panicum repens*) | 26 53 37N 81 04 30W | DT2 | 26 52 38N 81 04 20W | DT2B |
| Floating Hydrilla (*Hydrilla verticillata*) | 26 58 08N 81 01 44W | HY-FL1 | 26 57 51N 81 02 01W | HY-FL1B |
| Floating Hydrilla (*Hydrilla verticillata*) | 26 57 24N 81 03 02W | HY-FL2 | 26 57 30N 81 03 08W | HY-FL2B |
| Submerged Hydrilla (*Hydrilla verticillata*) | 26 57 15N 81 02 40W | HY-SU1 | 26 57 17N 81 02 36W | HY-SU1B |
| Submerged Hydrilla (*Hydrilla verticillata*) | 26 57 28N 81 03 05W | HY-SU2 | 26 57 35N 81 03 01W | HY-SU2B |
| Wet Spikerush (*Eleocharis* sp.) | 26 53 28N 81 02 31W | WE1 | 26 54 06N 81 01 44W | WE1B |
| Wet Spikerush (*Eleocharis* sp.) | 26 54 35N 81 02 07W | WE2 | 26 54 31N 81 01 59W | WE2B |
| Wet Torpedograss (*Panicum repens*) | 26 54 01N 81 04 20W | WT1 | 26 53 57N 81 04 19W | WT1B |
| Wet Torpedograss (*Panicum repens*) | 26 53 36N 81 04 10W | WT2 | 26 52 29N 81 04 17W | WT2B |

* Corrected values

## Table 2. Avifaunal Groupings Sampled During All Events

| | | |
|---|---|---|
| **Arboreal Birds** [a] | | |
| BGGN | Blue-gray gnatcatcher (*Polioptila caerulea*) | Resident |
| BTGR | Boat-tailed grackle (*Quiscalus major*) | Resident |
| CAWR | Carolina wren (*Thryothorus ludovicianus*) | Resident |
| COYE | Common yellowthroat (*Geothlypis trichas*) | Resident |
| DOWO | Downey woodpecker (*Picoides pubescens*) | Resident |
| EAKI | Eastern kingbird (*Tyrannus tyrannus*) | Migrant |
| EAME | Eastern meadowlark (*Sturnella magna*) | Resident |
| EAPH | Eastern phoebe (*Sayornis phoebe*) | Migrant |
| FICR | Fish crow (*Corvus ossifragus*) | Resident |
| KILL | Killdeer (*Charadrius vociferus*) | Resident |
| MAWR | Marsh wren (*Cistothorus palustris*) | Migrant |
| NOCA | Northern cardinal (*Cardinalis cardinalis*) | Resident |
| NRWS | Northern rough-winged swallow (*Stelgidopteryx serripennis*) | Migrant |
| PAWA | Palm warbler (*Dendroica palmarum*) | Migrant |
| PIWO | Pileated woodpecker (*Dryocopus pileatus*) | Resident |
| RBWO | Red-bellied woodpecker (*Melanerpes carolinus*) | Resident |
| RWBL | Red-winged blackbird (*Agelaius phoeniceus*) | Resident |
| SASP | Savannah sparrow (*Passerculus sandwichensis*) | Migrant |
| SEWR | Sedge wren (*Cistothorus platensis*) | Migrant |
| SWSP | Swamp sparrow (*Melospiza georgiana*) | Migrant |
| WEVI | White-eyed vireo (*Vireo griseus*) | Resident |
| YRWA | Yellow-rumped warbler (*Dendroica coronata*) | Migrant |
| **Aerial Feeding Birds** [b] | | |
| BASW | Barn swallow (*Hirundo rustica*) | Migrant |
| CHSW | Chimney swift (*Chaetura pelagica*) | Migrant |
| GULL | Gull species | Migrant |
| PUMA | Purple martin (*Progne subis*) | Migrant |
| TRSW | Tree swallow (*Tachycineta bicolor*) | Migrant |
| **Aerial Searching Birds** [a] | | |
| BEKI | Belted kingfisher (*Ceryle alcyon*) | Resident |
| BLTE | Black tern (*Chlidonias niger*) | Migrant |
| CATE | Caspian tern (*Sterna caspia*) | Resident |
| FOTE | Forster's tern (Sterna Forsteri) | Migrant |
| LAGU | Laughing gull (*Larus atricilla*) | Resident |
| RBGU | Ring-billed gull (*Larus delawarensis*) | Resident |
| RUDU | Ruddy duck (*Oxyura jamaicensis*) | Resident |
| **Floating and Diving Birds** [a] | | |
| ANHI | American anhinga (*Anhinga anhinga*) | Resident |
| AMCO | American coot (*Fulica americana*) | Migrant |
| AWPE | American white pelican (*Pelicanus erythrorhyncus*) | Resident |
| BRPE | Brown pelican (*Pelicanus occidentalis*) | Resident |
| COMO | Common gallinule (*Gallinula chloropus*) | Resident |
| COLO | Common loon (*Gravia immer*) | Migrant |
| DCCO | Double-crested cormorant(*Phalacrocorax auritas*) | Resident |
| PBGR | Pied-billed grebe (*Podilymbus podiceps*) | Resident |
| PUGA | Purple gallinule (*Porphyrula martinica*) | Resident |

| | | |
|---|---|---|
| **Table 2 - continued** | | |
| **Raptors and Vultures** [b] | | |
| MAKE | American kestrel (*Falco sparverius*) | Resident |
| ASKI | American swallow-tailed kite (Elanoides Forficatus) | Migrant |
| BAEA | Bald eagle (*Haliaeetus leucocephalus*) | Resident |
| NOHA | Northern harrier (*Circus cyaneus*) | Migrant |
| OSPR | Osprey (*Pandion haliaetus*) | Resident |
| PEFA | Peregrine falcon (*Falco peregrinus*) | Migrant |
| RSHA | Red-shouldered hawk (*Buteo lineatus*) | Resident |
| SNKI | Snail kite (*Rostrhamus sociabilis*) | Resident |
| TUVU | Turkey vulture (*Cathartes aura*) | Resident |
| **Shorebirds** [a] | | |
| BNST | Black-necked stilt (*Himantopus mexicanus*) | Migrant |
| DUNL | Dunlin (*Calidris alpina*) | Migrant |
| GRYE | Greater yellowlegs (*Tringa melanoleuca*) | Migrant |
| LESA | Least sandpiper (*Calidris minulilla*) | Migrant |
| LEYE | Lesser yellowlegs (*Tringa flavipes*) | Migrant |
| STSA | Stilt sandpiper (*Calidris himantopus*) | Migrant |
| **Surface Feeding Ducks** [b] | | |
| BWTE | Blue-winged teal (*Anas discors*) | Migrant |
| DUCK | Duck species | Migrant |
| FWDU | Fulvous whistling duck (*Dendrocygna bicolor*) | Resident |
| MODU | Mottled duck (*Anas fulvigula)* | Resident |
| RNDU | Ring-necked duck (*Aythya collaris*) | Migrant |
| **Wading Birds** [a] **Long Legged** [b] | | |
| GBHE | Great blue heron (*Ardea herodias*) | Resident |
| GREG | Great egret (*Casmerodius albus*) | Resident |
| SACR | Sandhill crane (*Grus canadensis)* | Resident |
| **Wading Birds** [a] **Short Legged** [b] | | |
| AMBI | American bittern (*Botaurus lentiginosus*) | Migrant |
| GLIB | Glossy ibis (*Plegadis falcinellus*) | Resident |
| GRHE | Green-backed heron (*Butorides striatus*) | Resident |
| KIRA | King rail (*Rallus elagans*) | Resident |
| LEBI | Least bittern (*Ixobrychus exilis*) | Resident |
| LIMP | Limpkin (*Aramus guarauna*) | Resident |
| LBHE | Little blue heron (*Egretta caerulea*) | Resident |
| SNEG | Snowy egret (*Egretta thula*) | Resident |
| SORA | Sora rail (*Porzana carolina*) | Migrant |
| TRHE | Tricolored heron (*Egretta tricolor*) | Resident |
| WHIB | White ibis (*Eudocimus albus*) | Resident |
| | | |
| [a] Avifaunal Groups taken from Drew and Schomer (1984) | | |
| [b] Supplemental Avifaunal Groups | | |

## Table 3. General Weather Conditions at the Time of Sampling

| | General | Temperatures (°C) | | | |
|---|---|---|---|---|---|
| Sampling Dates | Weather Conditions | High | Average | Low | Precipitation (cm) |
| 5/5/97 | Clear to 10% cloud cover | 26.7 | 22.8 | 18.9 | None observed |
| 5/6/97 | Clear to 10% cloud cover | 28.2 | 23.0 | 17.8 | None observed |
| 5/7/97 | Clear to 20% cloud cover | 30.0 | 23.6 | 17.2 | None observed |
| 5/8/97 | Clear to 10% cloud cover | 29.4 | 23.3 | 17.2 | None observed |
| 5/9/97 | Clear to 20% cloud cover | 29.2 | 23.0 | 16.7 | None observed |
| 5/10/97 | Clear to < 5% cloud cover | 30.3 | 30.3 | NA | None observed |
| 7/28/97 | Clear to Overcast | 32.3 | 28.4 | 24.5 | 2.24 |
| 7/29/97 | Clear to 40% cloud cover | 31.7 | 27.5 | 23.2 | 0.05 |
| 7/30/97 | Clear to 40% cloud cover | 32.0 | 27.4 | 22.8 | 0.03 |
| 7/31/97 | Clear to Overcast | 31.0 | 26.2 | 21.4 | 2.54 |
| 8/1/97 | Clear to Overcast | 32.8 | 27.6 | 22.4 | 2.32 |
| 8/2/97 | Clear to 10% cloud cover | 33.5 | 29.1 | 24.7 | None observed |
| 10/27/97 | Clear to Overcast | 33.3 | 30.3 | 27.2 | None observed |
| 10/28/97 | Clear to Overcast | 30.6 | 23.1 | 15.6 | None observed |
| 10/29/97 | Clear to 60% cloud cover | 30.2 | 23.0 | 15.8 | None observed |
| 10/30/97 | Overcast | 27.8 | 24.5 | 21.1 | None observed |
| 10/31/97 | Overcast | 28.3 | 25.6 | 22.8 | None observed |
| 11/1/97 | Overcast to Clear | 30.6 | 22.3 | 13.9 | None observed |
| 1/6/98 | 5% to 10% cloud cover | 27.0 | 26.0 | 25.0 | None observed |
| 1/7/98 | Clear to 90% cloud cover | 28.0 | 27.0 | 26.0 | None observed |
| 1/8/98 | 40% to Overcast | 27.0 | 25.0 | 23.0 | 1.32 |
| 1/9/98 | 10% to 90% cloud cover | 27.0 | 25.5 | 24.0 | None observed |
| 1/10/98 | 10% to 75% cloud cover | 23.0 | 21.0 | 19.0 | None observed |
| 1/11/98 | 10% to 65% cloud cover | 21.0 | 18.5 | 16.0 | None observed |
| 3/9/98 | 50% to 90% cloud cover | 19.0 | 17.8 | 16.5 | None observed |
| 3/10/98 | 80% to 100% cloud cover | 18.0 | 15.5 | 13.0 | None observed |
| 3/11/98 | Clear to 50% cloud cover | 18.2 | 16.6 | 15.0 | None observed |
| 3/12/98 | 15% to 100% cloud cover | 18.5 | 14.3 | 10.0 | None observed |
| 3/13/98 | Clear to 100% cloud cover | 21.5 | 19.8 | 18.0 | None observed |
| 3/14/98 | 20% cloud cover | 18.5 | 18.0 | 17.5 | None observed |
| 6/2/98 | 25% to 50% cloud cover | 33.9 | 28.4 | 22.8 | None observed |
| 6/3/98 | 20% to 30% cloud cover | 34.4 | 28.6 | 22.8 | None observed |
| 6/4/98 | Clear | 35.0 | 28.4 | 21.7 | None observed |
| 6/5/98 | Clear to 30% cloud cover | 35.6 | 28.7 | 21.7 | None observed |
| 6/6/98 | 20% to 100% cloud cover | 36.7 | 28.5 | 23.3 | None observed |
| 9/14/98 | 20% to 35% cloud cover | 29.0 | 28.5 | 28.0 | None observed |
| 9/15/98 | 30% to 80% cloud cover | 32.0 | 29.5 | 27.0 | 0.43 |
| 9/16/98 | 100% cloud cover | 26.5 | 26.3 | 26.0 | None observed |
| 9/17/98 | 40% to 90% cloud cover | 31.0 | 29.0 | 27.0 | 2.12 |
| 9/18/98 | 75% to,100% cloud cover | 31.0 | 28.5 | 26.0 | 0.24 |
| 9/19/98 | 75% to 80% cloud cover | 31.0 | 24.5 | 26.0 | 0.06 |
| 11/17/98 | 5% to 80% cloud cover | 26.0 | 24.5 | 23.0 | None observed |
| 11/18/98 | 15% to 30% cloud cover | 30.0 | 28.5 | 27.0 | None observed |
| 11/19/98 | 10% to 30% cloud cover | 30.0 | 28.5 | 27.0 | None observed |
| 11/20/98 | 0% cloud cover | 30.0 | 30.0 | 30.0 | None observed |
| 11/21/98 | 25% to 80% cloud cover | 28.0 | 27.0 | 26.0 | None observed |

## Table 4. Water Depth Recorded at Sampling Points in Spikerush Habitat For All Events

| Drift Fences | | | | |
|---|---|---|---|---|
| **Sampling Event** | **Sampling Point** | **Maximum (cm)** | **Average (cm)** | **Minimum (cm)** |
| May-97 | DFDE1 | 0.0 | 0.0 | 0.0 |
| | DFDE2 | 0.0 | 0.0 | 0.0 |
| | DFWE1 | 45.1 | 44.6 | 44.0 |
| | DFWE2 | 47.0 | 46.8 | 46.5 |
| Jul-97 | DFDE1 | 3.0 | 3.0 | 3.0 |
| | DFDE2 | 5.0 | 4.4 | 3.8 |
| | DFWE1 | 65.5 | 65.5 | 65.5 |
| | DFWE2 | 66.0 | 65.8 | 65.6 |
| Oct-97 | DFDE1 | 31.5 | 31.0 | 30.5 |
| | DFDE2 | 38.1 | 36.6 | 35.0 |
| Jan-98 | DFDE1 | 95.5 | 91.0 | 86.4 |
| | DFDE2 | 137.7 | 116.1 | 94.5 |
| | DFWE1 | 138.7 | 133.9 | 129.0 |
| | DFWE2 | 137.5 | 131.0 | 124.5 |
| Mar-98 | DFDE1 | 156.4 | 152.5 | 148.5 |
| | DFDE2 | 151.0 | 147.8 | 144.5 |
| | DFWE1 | 169.0 | 165.3 | 161.5 |
| | DFWE2 | 171.5 | 168.0 | 164.5 |
| Jun-98 | DFDE1 | 33.3 | 32.0 | 31.3 |
| | DFDE2 | 38.8 | 38.5 | 37.8 |
| | DFWE1 | 107.0 | 106.0 | 105.0 |
| | DFWE2 | 112.0 | 111.0 | 110.0 |
| Sep-98 | DFDE1 | 33.0 | 91.0 | 26.7 |
| | DFDE2 | 35.6 | 116.1 | 29.8 |
| | DFWE1 | 101.6 | 133.9 | 99.1 |
| | DFWE2 | 101.9 | 131.0 | 99.2 |
| Nov-98 | DFDE1 | 75.9 | 73.2 | 70.5 |
| | DFDE2 | 75.5 | 73.0 | 70.5 |
| | DFWE1 | 150.5 | 143.9 | 137.2 |
| | DFWE2 | 146.7 | 139.7 | 132.7 |
| **Bird Transects** | | | | |
| **Sampling Event** | **Sampling Point** | **Maximum (cm)** | **Average (cm)** | **Minimum (cm)** |
| May-97 | DE1/DE1B | 0.0 | 0.0 | 0.0 |
| | DE2/DE2B | 0.0 | 0.0 | 0.0 |
| | WE1/WE1B | 44.5 | 44.5 | 44.5 |
| | WE2/WE2B | 63.5 | 62.9 | 62.2 |
| Jul-97 | DE1/DE1B | 5.1 | 5.1 | 5.1 |
| | DE2/DE2B | 1.9 | 1.0 | 0.0 |
| | WE1/WE1B | 63.5 | 63.5 | 63.5 |
| | WE2/WE2B | 83.8 | 80.0 | 76.2 |
| Oct-97 | DE1/DE1B | 39.4 | 37.5 | 35.6 |
| | DE2/DE2B | 78.7 | 76.8 | 74.9 |
| | WE1/WE1B | 134.6 | 132.7 | 130.8 |
| | WE2/WE2B | 125.7 | 121.9 | 118.1 |
| Jan-98 | DE1/DE1B | 91.4 | 89.5 | 87.6 |
| | DE2/DE2B | 125.7 | 122.6 | 119.4 |
| | WE1/WE1B | 190.5 | 184.2 | 177.8 |
| | WE2/WE2B | 170.2 | 166.4 | 162.6 |
| Mar-98 | DE1/DE1B | 123.0 | 122.8 | 122.5 |
| | DE2/DE2B | 120.0 | 119.3 | 118.5 |
| | WE1/WE1B | 216.0 | 211.8 | 207.5 |
| | WE2/WE2B | 200.0 | 198.0 | 196.0 |
| Jun-98 | DE1/DE1B | 37.5 | 33.8 | 30.0 |
| | DE2/DE2B | 35.0 | 33.8 | 32.5 |
| | WE1/WE1B | 107.5 | 106.4 | 105.3 |
| | WE2/WE2B | 125.5 | 119.0 | 112.5 |
| Sep-98 | DE1/DE1B | 33.0 | 31.8 | 30.5 |
| | DE2/DE2B | 33.0 | 30.5 | 27.9 |
| | WE1/WE1B | 106.7 | 104.8 | 102.9 |
| | WE2/WE2B | 124.5 | 120.7 | 116.8 |
| Nov-98 | DE1/DE1B | 73.7 | 73.7 | 73.7 |
| | DE2/DE2B | 87.6 | 87.6 | 87.6 |
| | WE1/WE1B | 163.8 | 160.0 | 156.2 |
| | WE2/WE2B | 141.0 | 141.0 | 141.0 |

**Table 5. Water Depth Recorded at Sampling Points in Cattail Habitat For All Events**

| Drift Fences | | | | |
|---|---|---|---|---|
| Sampling Event | Sampling Point | Maximum (cm) | Average (cm) | Minimum (cm) |
| May-97 | DFC1 | 64.8 | 62.1 | 59.3 |
| | DFC2 | 60.3 | 58.3 | 56.3 |
| | DFC3 | 71.1 | 69.8 | 68.4 |
| | DFC4 | 68.5 | 65.0 | 61.5 |
| Jul-97 | DFC1 | 95.0 | 87.1 | 67.3 |
| | DFC2 | 91.0 | 78.9 | 54.6 |
| | DFC3 | 69.5 | 63.6 | 55.9 |
| | DFC4 | 63.0 | 43.7 | 28.7 |
| Oct-97 | | * | * | * |
| Jan-98 | DFC1 | 148.0 | 146.0 | 144.0 |
| | DFC2 | 154.2 | 147.6 | 141.0 |
| | DFC3 | 110.0 | 106.5 | 103.0 |
| | DFC4 | 126.0 | 124.5 | 123.0 |
| Mar-98 | DFC1 | 226.5 | 221.8 | 217.0 |
| | DFC2 | 232.0 | 228.5 | 225.0 |
| | DFC3 | 211.5 | 203.8 | 196.0 |
| | DFC4 | 215.0 | 212.0 | 209.0 |
| Jun-98 | DFC1 | ** | ** | ** |
| | DFC2 | 98.0 | 96.5 | 95.0 |
| | DFC3 | ** | ** | ** |
| | DFC4 | ** | ** | ** |
| Sep-98 | DFC1 | 124.0 | 122.3 | 120.5 |
| | DFC2 | 119.2 | 117.8 | 116.3 |
| | DFC3 | 105.0 | 101.1 | 97.1 |
| | DFC4 | 88.3 | 84.7 | 81.1 |
| Nov-98 | DFC1 | 170.5 | 165.3 | 160.0 |
| | DFC2 | 168.0 | 162.8 | 157.5 |
| | DFC3 | 145.2 | 141.6 | 137.9 |
| | DFC4 | 131.8 | 126.8 | 121.8 |
| Bird Transects | | | | |
| Sampling Event | Sampling Point | Maximum (cm) | Average (cm) | Minimum (cm) |
| May-97 | CAT1/CAT1B | 96.5 | 86.4 | 76.2 |
| | CAT2/CAT2B | 104.1 | 101.6 | 99.1 |
| | CAT3/CAT3B | 50.8 | 49.9 | 48.9 |
| | CAT4/CAT4B | 48.3 | 47.0 | 45.7 |
| Jul-97 | CAT1/CAT1B | 124.5 | 119.4 | 114.3 |
| | CAT2/CAT2B | 142.2 | 142.2 | 142.2 |
| | CAT3/CAT3B | 78.7 | 73.7 | 68.6 |
| | CAT4/CAT4B | 61.0 | 59.7 | 58.4 |
| Oct-97 | CAT1/CAT1B | 160.0 | 157.5 | 154.9 |
| | CAT2/CAT2B | 152.4 | 151.8 | 151.1 |
| | CAT3/CAT3B | 116.8 | 111.8 | 106.7 |
| | CAT4/CAT4B | 104.1 | 102.9 | 101.6 |
| Jan-98 | CAT1/CAT1B | 180.3 | 177.8 | 175.3 |
| | CAT2/CAT2B | 218.4 | 218.4 | 218.4 |
| | CAT3/CAT3B | 172.7 | 170.2 | 167.6 |
| | CAT4/CAT4B | 165.1 | 165.1 | 165.1 |
| Mar-98 | CAT1/CAT1B | 248.5 | 248.2 | 247.9 |
| | CAT2/CAT2B | 255.0 | 254.3 | 253.5 |
| | CAT3/CAT3B | 165.5 | 162.0 | 158.5 |
| | CAT4/CAT4B | 211.0 | 205.5 | 200.0 |
| Jun-98 | CAT1/CAT1B | 177.5 | 170.8 | 164.0 |
| | CAT2/CAT2B | 167.5 | 165.0 | 162.5 |
| | CAT3/CAT3B | 118.0 | 114.0 | 110.0 |
| | CAT4/CAT4B | 111.0 | 110.0 | 109.0 |
| Sep-98 | CAT1/CAT1B | 172.7 | 165.1 | 157.5 |
| | CAT2/CAT2B | 162.6 | 160.1 | 157.5 |
| | CAT3/CAT3B | 116.8 | 116.8 | 116.8 |
| | CAT4/CAT4B | 109.2 | 108.0 | 106.7 |
| Nov-98 | CAT1/CAT1B | 196.9 | 195.0 | 193.0 |
| | CAT2/CAT2B | 199.4 | 188.0 | 176.5 |
| | CAT3/CAT3B | 111.8 | 108.0 | 104.1 |
| | CAT4/CAT4B | 139.7 | 135.3 | 130.8 |

* No herpetofaunal sampling occurred For October 1997 in cattails due to inclement weather.
** No herpetofaunal sampling occurred For June 1998 at drift fences DFC1, DFC3, DFC4 (unable to locate arrays)

**Table 6. Water Depths Recorded at Bird Transects in Hydrilla Habitat For All Events**

| Sampling Event | Sampling Point | Maximum (cm) | Average (cm) | Minimum (cm) |
|---|---|---|---|---|
| **May-97** | HY-SU1/HY-SU1B | 87.6 | 87.6 | 87.6 |
| | HY-SU2/HY-SU2B | 137.2 | 135.9 | 134.6 |
| | HY-FL1/HY-FL1B | 106.7 | 106.7 | 106.7 |
| | HY-FL2/HY-FL2B | 83.8 | 82.6 | 81.3 |
| **Jul-97** | HY-SU1/HY-SU1B | 106.7 | 105.4 | 104.1 |
| | HY-SU2/HY-SU2B | 149.9 | 148.6 | 147.3 |
| | HY-FL1/HY-FL1B | 123.2 | 121.3 | 119.4 |
| | HY-FL2/HY-FL2B | 101.6 | 97.8 | 94.0 |
| **Oct-97** | HY-SU1/HY-SU1B | 146.1 | 142.9 | 139.7 |
| | HY-SU2/HY-SU2B | 190.5 | 188.0 | 185.4 |
| | HY-FL1/HY-FL1B | 163.8 | 161.3 | 158.8 |
| | HY-FL2/HY-FL2B | 139.7 | 139.7 | 139.7 |
| **Jan-98** | HY-SU1/HY-SU1B | 208.3 | 207.0 | 205.7 |
| | HY-SU2/HY-SU2B | 256.5 | 256.5 | 256.5 |
| | HY-FL1/HY-FL1B | 261.6 | 259.7 | 257.8 |
| | HY-FL2/HY-FL2B | 204.5 | 203.9 | 203.2 |
| **Mar-98** | HY-SU1/HY-SU1B | 240.0 | 238.3 | 236.5 |
| | HY-SU2/HY-SU2B | * | * | * |
| | HY-FL1/HY-FL1B | * | * | * |
| | HY-FL2/HY-FL2B | 290.0 | 278.5 | 267.0 |
| **Jun-98** | HY-SU1/HY-SU1B | 152.0 | 151.5 | 151.0 |
| | HY-SU2/HY-SU2B | 203.0 | 195.3 | 187.5 |
| | HY-FL1/HY-FL1B | 161.0 | 157.5 | 154.0 |
| | HY-FL2/HY-FL2B | 151.0 | 146.0 | 141.0 |
| **Sep-98** | HY-SU1/HY-SU1B | 149.9 | 148.6 | 147.3 |
| | HY-SU2/HY-SU2B | 193.0 | 190.5 | 188.0 |
| | HY-FL1/HY-FL1B | 162.6 | 160.1 | 157.5 |
| | HY-FL2/HY-FL2B | 142.2 | 139.7 | 137.2 |
| **Nov-98** | HY-SU1/HY-SU1B | 186.7 | 186.1 | 185.4 |
| | HY-SU2/HY-SU2B | 246.4 | 240.7 | 235.0 |
| | HY-FL1/HY-FL1B | 218.4 | 210.8 | 203.2 |
| | HY-FL2/HY-FL2B | 182.9 | 182.9 | 182.9 |

* Site not sampled due to inclement weather

**Table 7. Water Depths Recorded at Sampling Points in Torpedograss Ha For All Events**

| Drift Fences | | | | |
|---|---|---|---|---|
| **Sampling Event** | **Sampling Point** | **Maximum (cm)** | **Average (cm)** | **Minimum (cm)** |
| **May-97** | DFDT1 | 0.0 | 0.0 | 0.0 |
| | DFDT2 | 0.0 | 0.0 | 0.0 |
| | DFWT1 | 3.0 | 1.5 | 0.0 |
| | DFWT2 | 8.0 | 4.0 | 0.0 |
| **Jul-97** | DFDT1 | 8.0 | 7.4 | 6.5 |
| | DFDT2 | 10.3 | 7.0 | 4.0 |
| | DFWT1 | 18.0 | 13.1 | 5.0 |
| | DFWT2 | 16.0 | 11.0 | 6.0 |
| **Oct-97** | DFDT1 | 52.0 | 44.5 | 37.0 |
| | DFDT2 | 54.0 | 46.5 | 39.0 |
| | DFWT1 | 52.0 | 48.0 | 44.0 |
| | DFWT2 | 55.0 | 47.5 | 40.0 |
| **Jan-98** | DFDT1 | 115.5 | 105.5 | 95.5 |
| | DFDT2 | 117.2 | 98.6 | 80.0 |
| | DFWT1 | 138.7 | 124.6 | 110.5 |
| | DFWT2 | 115.1 | 112.1 | 109.0 |
| **Mar-98** | DFDT1 | 153.0 | 147.3 | 141.5 |
| | DFDT2 | 149.5 | 146.0 | 142.5 |
| | DFWT1 | 167.5 | 160.0 | 152.5 |
| | DFWT2 | 165.0 | 156.0 | 147.0 |
| **Jun-98** | DFDT1 | 48.0 | 45.5 | 43.0 |
| | DFDT2 | 45.0 | 43.0 | 41.0 |
| | DFWT1 | 51.0 | 50.0 | 49.0 |
| | DFWT2 | 58.0 | 58.0 | 58.0 |
| **Sep-98** | DFDT1 | 44.5 | 42.3 | 40.0 |
| | DFDT2 | 43.2 | 41.3 | 39.4 |
| | DFWT1 | 51.8 | 49.1 | 46.4 |
| | DFWT2 | 55.0 | 54.5 | 54.0 |
| **Nov-98** | DFDT1 | 89.5 | 87.3 | 85.1 |
| | DFDT2 | 88.0 | 84.7 | 81.3 |
| | DFWT1 | 93.0 | 92.2 | 91.4 |
| | DFWT2 | 95.3 | 94.3 | 93.3 |
| **Bird Transects** | | | | |
| **Sampling Event** | **Sampling Point** | **Maximum (cm)** | **Average (cm)** | **Minimum (cm)** |
| **May-97** | DT1/DT1B | 6.4 | 3.2 | 0.0 |
| | DT2/DT2B | 0.0 | 0.0 | 0.0 |
| | WT1/WT1B | 6.4 | 5.1 | 3.8 |
| | WT2/WT2B | 3.8 | 2.6 | 1.3 |
| **Jul-97** | DT1/DT1B | 5.1 | 3.8 | 2.5 |
| | DT2/DT2B | 6.4 | 5.8 | 5.1 |
| | WT1/WT1B | 16.5 | 14.6 | 12.7 |
| | WT2/WT2B | 10.2 | 10.2 | 10.2 |
| **Oct-97** | DT1/DT1B | 66.0 | 62.9 | 59.7 |
| | DT2/DT2B | 47.0 | 46.4 | 45.7 |
| | WT1/WT1B | 55.9 | 48.3 | 40.6 |
| | WT2/WT2B | 58.4 | 55.9 | 53.3 |
| **Jan-98** | DT1/DT1B | 106.7 | 104.2 | 101.6 |
| | DT2/DT2B | 105.4 | 104.2 | 102.9 |
| | WT1/WT1B | 106.7 | 106.1 | 105.4 |
| | WT2/WT2B | 113.0 | 99.7 | 86.4 |
| **Mar-98** | DT1/DT1B | 134.5 | 133.2 | 131.9 |
| | DT2/DT2B | 134.5 | 131.8 | 129.0 |
| | WT1/WT1B | 144.0 | 130.0 | 116.0 |
| | WT2/WT2B | 134.5 | 127.3 | 120.0 |
| **Jun-98** | DT1/DT1B | 46.0 | 45.5 | 45.0 |
| | DT2/DT2B | 48.5 | 47.3 | 46.0 |
| | WT1/WT1B | 55.0 | 50.0 | 45.0 |
| | WT2/WT2B | 48.0 | 44.3 | 40.5 |
| **Sep-98** | DT1/DT1B | 47.0 | 47.0 | 47.0 |
| | DT2/DT2B | 45.7 | 45.7 | 45.7 |
| | WT1/WT1B | 63.5 | 58.4 | 53.3 |
| | WT2/WT2B | 53.3 | 39.7 | 26.0 |
| **Nov-98** | DT1/DT1B | 87.6 | 87.6 | 87.6 |
| | DT2/DT2B | 71.1 | 68.6 | 66.0 |
| | WT1/WT1B | 91.4 | 88.3 | 85.1 |
| | WT2/WT2B | 91.4 | 91.4 | 91.4 |

## Table 8a. Average Percent Coverage of Plant Species in Spikerush Habitat For All Drift Fences

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 4 | 3 | 0 | 0 | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 0 | 14 | 2 | 2 | 0 | 17 | 18 | 6 |
| Buttonbush (*Cephalanthus occidentalis*) | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cattail (*Typha* sp.) | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 0 | 0 | 0 | 0 | 0 | 8 | 5 | 4 |
| Green Algae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp. ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sedge (*Carex* spp. ) | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| **Spikerush (*Eleocharis* sp.)** | **76** | **21** | **52** | **20** | **3** | **42** | **18** | **42** |
| Stinkweed (*Pluchia* spp.) | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Torpedograss (*Panicum repens*) | 9 | 11 | 11 | 1 | 0 | 7 | 0 | 7 |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water hyacinth (*Eichhornia crassipes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Open Water | 9 | 0 | 30 | 78 | 97 | 28 | 59 | 41 |

Water too murky to identify vegetation during March 1998 sampling event.

**Table 8b. Average Percent Coverage of Plant Species in Spikerush Habitat For Avifauna Transects**

| | SAMPLING EVENT | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 | Average |
| Arrowhead (*Sagittaria lancifolia*) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 2 | 1 |
| Bladderwort (*Utricularia* spp.) | 18 | 23 | 9 | 0 | 0 | 0 | 14 | 8 | 9 |
| Buttonbush (*Cephalanthus occidentalis*) | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| Cattail (*Typha* sp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 6 | 3 | 1 | 2 | 0 | 0 | 1 | 0 | 2 |
| Green Algae | 0 | 0 | 0 | 0 | 0 | 0 | 18 | 13 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sedge (*Carex* spp.) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Spikerush (*Eleocharis* sp.)** | **26** | **11** | **8** | **9** | **4** | **8** | **2** | **0** | **8** |
| Stinkweed (*Pluchia* spp.) | 0 | 1 | 0 | 0 | 0 | 0 | 9 | 6 | 2 |
| Torpedograss (*Panicum repens*) | 4 | 3 | 7 | 3 | 0 | 8 | 0 | 0 | 3 |
| Umbrella sedge (*Cyperus* spp.) | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 2 | 1 |
| Water hyacinth (*Eichhornia crassipes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Open Water | 42 | 55 | 73 | 86 | 96 | 85 | 51 | 69 | 74 |

Water too murky to identify vegetation during March 1998 sampling event.

## Table 9a. Average Percent Coverage of Plant Species in Cattail Habitat For All Drift Fences

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 2 | 14 | * | 63 | 0 | 0 | 3 | 0 |
| Buttonbush (*Cephalanthus occidentalis*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| **Cattail (*Typha* sp.)** | **100** | **100** | * | **54** | **32** | **29** | **96** | **93** |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 31 | 8 | * | 0 | 0 | 0 | 2 | 3 |
| Fragrant waterlily (*Nymphea odorata*) | 0 | 0 | * | 0 | 0 | 66 | 2 | 3 |
| Green Algae | 0 | 0 | * | 9 | 1 | 0 | 0 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp.) | 0 | 0 | * | 2 | 1 | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Sedge (*Carex* spp.) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Spikerush (*Eleocharis* sp.) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Stinkweed (*Pluchia* spp.) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Torpedograss (*Panicum repens*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Water hyacinth (*Eichhornia crassipes*) | 1 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Water spangles (*Salvinia minima*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | * | 0 | 0 | 0 | 0 | 0 |
| Open Water | 0 | 0 | - | 0 | 66 | 5 | 0 | 2 |

* = No sampling occurred For October 1997 in cattails due to inclement weather.

**Table 9b. Average Percent Coverage of Plant Species in Cattail Habitat For Avifauna Transects**

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | 0 | 0 | * | 0 | 1 | 6 |
| Beakrush (*Rhynchospora* spp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 0 | 10 | 10 | 1 | * | 22 | 4 | 0 |
| Buttonbush (*Cephalanthus occidentalis*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| **Cattail (*Typha* sp.)** | **63** | **49** | **37** | **16** | * | **31** | **13** | **7** |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 2 | 0 | * | 0 | 2 | 6 |
| Coin wort (*Hydrocotyle umbellata*) | 1 | 0 | 3 | 2 | * | 6 | 21 | 64 |
| Common reed (*Phragmities australis*) | 0 | 0 | 0 | 0 | * | 0 | 3 | 0 |
| Cut grass (*Leersia* spp.) | 0 | 0 | 0 | 0 | * | 0 | 8 | 0 |
| Duckweed (*Lemna* spp.) | 1 | 0 | 0 | 0 | * | 0 | 3 | 0 |
| Eel grass (*Valisneria americana*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 4 | 0 | 0 | 30 | * | 16 | 71 | 70 |
| Green Algae | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 4 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Kosteketzkya (*Kosteketzkya* sp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp.) | 0 | 0 | 3 | 0 | * | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Polygonum (*Polygonum* sp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 1 |
| Primrose willow (*Ludwigia peruviana*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 3 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Sedge (*Carex* spp.) | 0 | 0 | 3 | 4 | * | 0 | 0 | 0 |
| Spikerush (*Eleocharis* sp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Stinkweed (*Pluchia* spp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Torpedograss (*Panicum repens*) | 8 | 0 | 0 | 0 | * | 0 | 6 | 1 |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Water hemlock (*Cicuta mexicana*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 3 |
| Water hyacinth (*Eichhornia crassipes*) | 0 | 0 | 0 | 0 | * | 3 | 0 | 16 |
| Water lettuce (*Pistia stratiotes*) | 6 | 0 | 12 | 10 | * | 63 | 47 | 6 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 3 | 0 | * | 0 | 5 | 0 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | 0 | 0 | * | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 9 | 0 | 0 | 0 | * | 0 | 0 | 3 |
| Open Water | 5 | 41 | 28 | 37 | - | 0 | 0 | 0 |

* = No sampling occurred For March 1998 in cattails due to inclement weather.

**Table 10. Average Percent Coverage of Plant Species in Hydrilla Habitat For Avifauna Transects**

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Buttonbush (*Cephalanthus occidentalis*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Cattail (*Typha* sp.) | 0 | 0 | 7 | * | * | 0 | 0 | 0 |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 1 | 0 | * | * | 0 | 0 | 0 |
| Common reed (*Phragmities australis*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Cut grass (*Leersia* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 0 | 0 | 9 | * | * | 0 | 0 | 0 |
| Eel grass (*Valisneria americana*) | 0 | 0 | 0 | * | * | 0 | 1 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Green Algae | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| **Hydrilla (*Hydrilla verticillata*)** | **94** | **92** | **44** | * | * | **0** | **94** | **38** |
| Kosteketzkya (*Kosteketzkya* sp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 1 | * | * | 0 | 0 | 0 |
| Polygonum (*Polygonum* sp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Sedge (*Carex* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Spikerush (*Eleocharis* sp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Stinkweed (*Pluchia* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Torpedograss (*Panicum repens*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Water hemlock (*Cicuta mexicana*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Water hyacinth (*Eichhornia crassipes*) | 6 | 3 | 16 | * | * | 0 | 6 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 1 | 0 | * | * | 0 | 0 | 51 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 4 | * | * | 0 | 0 | 1 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | 0 | * | * | 0 | 0 | 0 |
| Open Water | 0 | 3 | 19 | - | - | 100 | 0 | 11 |

* Water too murky to sample vegetation For January & March 1998

**Table 11a. Average Percent Coverage of Plant Species in Torpedograss Habitat For All Drift Fences**

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Buttonbush (*Cephalanthus occidentalis*) | 3 | 4 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cattail (*Typha* sp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 0 | 0 | 0 | 0 | 0 | 2 | 1 | 2 |
| Green Algae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sedge (*Carex* spp.) | 0 | 0 | 3 | 0 | 0 | 0 | 0 | 0 |
| Spikerush (*Eleocharis* sp.) | 5 | 6 | 14 | 16 | 1 | 1 | 5 | 5 |
| Stinkweed (*Pluchia* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Torpedograss (*Panicum repens*)** | **92** | **90** | **78** | **96** | **97** | **88** | **65** | **67** |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water hyacinth (*Eichhornia crassipes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wild rice (*Zizania aquatica*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Open Water | 0 | 0 | 4 | 0 | 3 | 9 | 23 | 24 |

**Table 11b. Average Percent Coverage of Plant Species in Torpedograss Habitat For Avifauna Transects**

| | SAMPLING EVENT | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Species Name | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Arrowhead (*Sagittaria lancifolia*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Beak rush (Rhynchospora spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Bladderwort (*Utricularia* spp.) | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 1 |
| Buttonbush (*Cephalanthus occidentalis*) | 2 | 2 | 0 | 0 | 0 | 0 | 1 | 0 |
| Cattail (*Typha* sp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Climbing hempvine (*Mikania scandens*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coin wort (*Hydrocotyle umbellata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Duckweed (*Lemna* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Fragrant waterlily (*Nymphea odorata*) | 4 | 0 | 8 | 2 | 1 | 11 | 82 | 8 |
| Green Algae | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hydrilla (*Hydrilla verticillata*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Lotus (*Nelumbo* spp. ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Mosquito fern (*Azolla caroliniana*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Punk tree (*Melaleuca quinquenervia*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sawgrass (*Cladium jamaicense*) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sedge (*Carex* spp. ) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Spikerush (*Eleocharis* sp.) | 1 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| Stinkweed (*Pluchia* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| **Torpedograss (*Panicum repens*)** | **88** | **95** | **72** | **100** | **74** | **97** | **29** | **95** |
| Umbrella sedge (*Cyperus* spp.) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water hyacinth (*Eichhornia crassipes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water lettuce (*Pistia stratiotes*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Water spangles (*Salvinia minima*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Wild rice (*Zizania aquatica*) | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Yellow cowlilly (*Nuphar luteum*) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Open Water | 4 | 0 | 19 | 0 | 25 | 0 | 0 | 0 |

**Table 12a. Herpetofauna Sampled For Spikerush Habitat For All Sampling Events**

| | SPIKERUSH | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** | **May-97** | **Jul-97** | **Oct-97** | **Jan-98** | **Mar-98** | **Jun-98** | **Sep-98** | **Nov-98** |
| American Alligator (Alligator mississippiensis) | 1 | 1 | | | | | | |
| Two-toed amphiuma (*Amphiuma means*) | | | | | | | | |
| Banded water snake (*Nerodia fasciata*) | | | | | | | | |
| Common snapping turtle (*Chelydra serpentina*) | | | | 1 | | | | |
| Cottonmouth (*Agkistrodon piscivorus*) | | | | | | | | |
| Florida brown snake (*Nerodia taxispilota*) | | | | | | 2 | | |
| Florida green water snake (*Nerodia floridana*) | 16 | | 11 | | | 6 | 2 | 1 |
| Greater siren (*Siren lacertina*) | | | 11 | | | 1 | 2 | 12 |
| Peninsula newt (*Notophthalmus viridescens*) | | | | | | | | |
| Peninsula ribbon snake (*Thamnophis sauritus*) | | | | | | | | |
| Pig frog (*Rana grylio*) | 6 | 2 | 4 | | | | | |
| Southeastern five-linked skink (*Eumeces inexpectatus*) | 1 | | | | | | | |
| Southern cricket frog (*Acris gryllus*) | | 3 | | | | | | |
| Southern leopard frog (*Rana utricularia*) | | 3 | | | | | | |
| Squirrel tree frog (*Hyla squirrela*) | | | 1 | | | | | |
| Striped mud turtle (*Kinosternon bauri*) | | | | | | | | |
| **Species Abundance** | **24** | **9** | **27** | **1** | **0** | **9** | **4** | **13** |
| **Species Richness** | **4** | **4** | **4** | **1** | **0** | **3** | **2** | **2** |

**Table 12b. Herpetofauna Sampled For Cattail Habitat For All Sampling Events**

| | CATTAIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| American Alligator (Alligator mississippiensis) | | | | | | | | |
| Two-toed amphiuma (*Amphiuma means*) | | 7 | | | | | | |
| Banded water snake (*Nerodia fasciata*) | 4 | | | | | | | |
| Cottonmouth (*Agkistrodon piscivorus*) | | 2 | | | | | | |
| Florida brown snake (*Nerodia taxispilota*) | | | | | | | | |
| Florida green water snake (*Nerodia floridana*) | | | | | | | | |
| Greater siren (*Siren lacertina*) | 3 | 10 | | | | 1 | 1 | 1 |
| Peninsula newt (*Notophthalmus viridescens*) | | 5 | | | | | | |
| Peninsula ribbon snake (*Thamnophis sauritus*) | | | | | | | | |
| Pig frog (*Rana grylio*) | | 6 | | | | 2 | | |
| Southeastern five-linked skink (*Eumeces inexpectatus*) | | | | | | | | |
| Southern cricket frog (*Acris gryllus*) | | | | | | | | |
| Southern leopard frog (*Rana utricularia*) | | | | | | | | |
| Squirrel tree frog (*Hyla squirrela*) | | | | | | | | |
| Striped mud turtle (*Kinosternon bauri*) | | | | | | | | |
| **Species Abundance** | **7** | **30** | ***** | **0** | **0** | **3** | **1** | **1** |
| **Species Richness** | **2** | **5** | ***** | **0** | **0** | **2** | **1** | **1** |

* No sampling occurred For October 1997 in cattails due to inclement weather

**Table 12c. Herpetofauna Sampled For Torpedograss Habitat For All Sampling Events**

| SPECIES | TORPEDOGRASS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| American Alligator (Alligator mississippiensis) | | | | | | 1 | | |
| Two-toed amphiuma (*Amphiuma means*) | | 1 | | | | 1 | 3 | 1 |
| Banded water snake (*Nerodia fasciata*) | | 1 | | | | | | |
| Cottonmouth (*Agkistrodon piscivorus*) | | | | | | | | |
| Florida brown snake (*Nerodia taxispilota*) | | | | | | | 2 | |
| Florida green water snake (*Nerodia floridana*) | | 1 | 7 | | | 10 | 6 | 2 |
| Greater siren (*Siren lacertina*) | | | 30 | | | 2 | 1 | 12 |
| Peninsula newt (*Notophthalmus viridescens*) | | | | | | | 2 | |
| Peninsula ribbon snake (*Thamnophis sauritus*) | 1 | | | | | | | |
| Pig frog (*Rana grylio*) | | 1 | 6 | | | | 1 | |
| Southeastern five-linked skink (*Eumeces inexpectatus*) | | | | | | | | |
| Southern cricket frog (*Acris gryllus*) | | | | | | | | |
| Southern leopard frog (*Rana utricularia*) | 1 | 2 | | | | | | |
| Squirrel tree frog (*Hyla squirrela*) | | | 2 | | | | | |
| Striped mud turtle (*Kinosternon bauri*) | | 1 | | | | | | |
| **Species Abundance** | **2** | **7** | **45** | **0** | **0** | **14** | **15** | **15** |
| **Species Richness** | **2** | **6** | **4** | **0** | **0** | **4** | **6** | **3** |

## Table 13a. Avifauna Sampled in Wet Spikerush Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 53.68 | 71.80 | 127.30 | 175.28 | 180.25 | 113.00 | 112.73 | 130.05 |
| | | | | | | | | |
| **Arboreal Birds** | **21** | **8** | **3** | **3** | **8** | **123** | **5** | **6** |
| Boat-tailed grackle | 9 | | 1 | 3 | 4 | 30 | 2 | 3 |
| Common yellowthroat | | | 1 | | | 1 | | |
| Marsh wren | | | | | | | | 1 |
| Palm warbler | | | 1 | | | | | |
| Red-winged blackbird | 12 | 8 | | | 4 | 92 | 3 | 2 |
| **Aerial Feeding Birds** | **0** | **4** | **4** | **75** | **112** | **0** | **20** | **0** |
| Barn swAllow | | 4 | 1 | | | | 14 | |
| Tree swAllow | | | 3 | 75 | 112 | | 6 | |
| **Aerial Searching Birds** | **0** | **0** | **1** | **0** | **2** | **0** | **3** | **1** |
| Belted kingfisher | | | 1 | | | | | 1 |
| Black tern | | | | | | | 3 | |
| Caspian tern | | | | | 1 | | | |
| Ring-billed gull | | | | | 1 | | | |
| **Floating and Diving Birds** | **39** | **25** | **5** | **137** | **3** | **41** | **26** | **153** |
| American coot | | | | 66 | | 1 | | 41 |
| American anhinga | | | | | | 1 | | |
| Brown pelican | | | | | 1 | | | |
| Common loon | | | | | | | | 1 |
| Common gallinule | 33 | 17 | 4 | 67 | 2 | 37 | 24 | 110 |
| Pied-billed grebe | 3 | 1 | | 4 | | 1 | | |
| Purple gAllinule | 3 | 7 | 1 | | | 1 | 2 | 1 |
| **Raptors and Vultures** | **14** | **3** | **3** | **2** | **7** | **3** | **1** | **8** |
| Northern harrier | | | | | | | | 7 |
| Osprey | 1 | | | | 1 | | 1 | |
| Peregrine falcon | | | | | | | | 1 |
| Snail kite | 13 | 3 | 2 | 2 | 6 | 3 | | |
| Turkey vulture | | | 1 | | | | | |
| **Shorebirds** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| Black-necked stilt | 1 | | | | | | | |
| **Surface Feeding Ducks** | **2** | **0** | **0** | **18** | **212** | **0** | **0** | **14** |
| Blue-winged teal | | | | | | | | 3 |
| Mottled duck | 2 | | | | | | | |
| Ring-necked duck | | | | 18 | 212 | | | 11 |
| **Long Legged Wading Birds** | **18** | **6** | **2** | **0** | **0** | **6** | **1** | **0** |
| Great blue heron | 1 | 1 | | | | 2 | | |
| Great egret | 17 | 5 | 2 | | | 4 | 1 | |
| **Short Legged Wading Birds** | **1** | **0** | **0** | **0** | **0** | **2** | **0** | **2** |
| Green-backed heron | | | | | | 1 | | |
| King rail | | | | | | | | 1 |
| Least bittern | 1 | | | | | | | |
| Tricolored heron | | | | | | 1 | | 1 |
| **SPECIES RICHNESS** | **96** | **46** | **18** | **235** | **344** | **175** | **56** | **184** |
| **SPECIES ABUNDANCE** | **10** | **7** | **9** | **6** | **10** | **10** | **8** | **10** |

# Table 13b. Avifauna Sampled in Dry Spikerush Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 0.00 | 2.38 | 57.15 | 106.03 | 121.00 | 34.00 | 31.10 | 80.65 |
| | | | | | | | | |
| **Arboreal Birds** | **5** | **3** | **4** | **29** | **25** | **59** | **3** | **17** |
| Boat-tailed grackle | | | | 15 | 7 | 24 | 1 | 2 |
| Common yellowthroat | 1 | 1 | | 3 | 11 | 3 | | |
| Downy woodpecker | | | | 1 | | | | |
| Eastern kingbird | | | | | | 1 | | |
| Fish Crow | 1 | | | | 2 | | | |
| Northern cardinal | | 2 | | | 1 | | | 1 |
| Palm warbler | | | | 6 | | | | 2 |
| Pileated woodpecker | | | | | | | 2 | |
| Red-bellied woodpecker | 1 | | 1 | 1 | | 1 | | 1 |
| Red-winged blackbird | 2 | | 3 | 3 | 3 | 29 | | 8 |
| Swamp sparrow | | | | | 1 | | | |
| White-eyed vireo | | | | | | 1 | | |
| Yellow-rumped warbler | | | | | | | | 3 |
| **Aerial Feeding Birds** | **0** | **0** | **0** | **1** | **25** | **0** | **0** | **5000** |
| Tree swallow | | | | 1 | 25 | | | 5000 |
| **Aerial Searching Birds** | **0** | **0** | **3** | **2** | **1** | **0** | **2** | **3** |
| Belted kingfisher | | | 3 | 2 | 1 | | 2 | |
| Caspian tern | | | | | | | | 3 |
| **Floating and Diving Birds** | **1** | **1** | **2** | **3** | **11** | **10** | **4** | **6** |
| American anhinga | | | | | | 1 | | |
| Common loon | | | | | | | | 6 |
| Common gAllinule | 1 | 1 | 2 | 2 | 11 | 9 | 4 | |
| Pied-billed grebe | | | | 1 | | | | |
| **Raptors and Vultures** | **2** | **4** | **9** | **7** | **4** | **2** | **4** | **9** |
| American kestrel | | | 3 | | 1 | | | |
| Bald Eagle | | | 1 | | | | | |
| Osprey | | 1 | 3 | 4 | 1 | | 2 | 7 |
| Red-shouldered hawk | 2 | 3 | 1 | 1 | 2 | | 1 | 2 |
| Snail kite | | | | | | 2 | 1 | |
| Turkey vulture | | | 1 | 2 | | | | |
| **Surface Feeding Ducks** | **1** | **0** | **2** | **0** | **2** | **3** | **3** | **25** |
| Duck species | | | | | | | | 1 |
| Mottled duck | 1 | | 2 | | 2 | 3 | 3 | |
| Ring-necked duck | | | | | | | | 24 |
| **Long Legged Wading Birds** | **4** | **0** | **0** | **2** | **0** | **3** | **1** | **0** |
| Great blue heron | | | | 1 | | | | |
| Great egret | | | | 1 | | 3 | 1 | |
| Sandhill crane | 4 | | | | | | | |
| **Short Legged Wading Birds** | **0** | **0** | **0** | **1** | **0** | **0** | **2** | **4** |
| Little blue heron | | | | | | | | 1 |
| Snowy egret | | | | | | | | 1 |
| Tricolored heron | | | | 1 | | | 1 | 2 |
| White Ibis | | | | | | | 1 | |
| **SPECIES RICHNESS** | **13** | **8** | **20** | **45** | **68** | **77** | **19** | **5064** |
| **SPECIES ABUNDANCE** | **8** | **5** | **10** | **16** | **13** | **11** | **11** | **16** |

## Table 14. Avifauna Sampled in Cattail Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 71.33 | 98.75 | 131.01 | 182.86 | 211.49 | 140.13 | 137.48 | 156.59 |
| | | | | | | | | |
| **Arboreal Birds** | **73** | **4** | **19** | **25** | **527** | **120** | **87** | **49** |
| Boat-tailed grackle | 19 | | 2 | | 21 | 35 | 35 | 10 |
| Common yellowthroat | 3 | 1 | 6 | 4 | 1 | 7 | 5 | 17 |
| Marsh wren | | | 6 | 4 | 1 | | | 4 |
| Palm warbler | | | 1 | 2 | 1 | | | 3 |
| Red-winged blackbird | 51 | 3 | 4 | 15 | 502 | 78 | 47 | 15 |
| Yellow-rumped warbler | | | | | 1 | | | |
| **Aerial Feeding Birds** | **0** | **0** | **0** | **0** | **2085** | **0** | **0** | **0** |
| Tree swAllow | | | | | 2085 | | | |
| **Floating and Diving Birds** | **39** | **33** | **11** | **17** | **31** | **60** | **22** | **26** |
| American coot | | | | | | 11 | | 3 |
| Common loon | | | | | | 1 | | |
| Common gallinule | 31 | 9 | 8 | 15 | 31 | 41 | 12 | 19 |
| Purple gallinule | 8 | 24 | 3 | 2 | | 7 | 10 | 4 |
| **Raptors and Vultures** | **2** | **0** | **0** | **4** | **4** | **0** | **0** | **3** |
| Northern harrier | | | | | 1 | | | |
| Turkey vulture | 2 | | | 4 | 3 | | | 3 |
| **Shorebirds** | **1** | **0** | **0** | **0** | **0** | **0** | **0** | **0** |
| Black-necked stilt | 1 | | | | | | | |
| **Surface Feeding Ducks** | **0** | **0** | **0** | **0** | **0** | **2** | **0** | **0** |
| Mottled duck | | | | | | 2 | | |
| **Long Legged Wading Birds** | **0** | **0** | **1** | **0** | **1** | **0** | **0** | **1** |
| Great blue heron | | | 1 | | | | | 1 |
| Great egret | | | | | 1 | | | |
| **Short Legged Wading Birds** | **14** | **8** | **2** | **2** | **4** | **12** | **12** | **6** |
| American bittern | | | | | | | | 1 |
| Glossy ibis | 5 | | | | 1 | | | |
| Green-backed heron | 4 | | 1 | | | | | |
| King rail | | 3 | | 1 | | 5 | 7 | 2 |
| Little blue heron | | | | | 2 | | | |
| Least bittern | 4 | 5 | | | | 5 | 5 | |
| Limpkin | | | | | | | | 2 |
| Snowy egre | | | | | 1 | | | |
| Sora rail | | | 1 | | | | | 1 |
| Tricolored heron | | | | 1 | | 2 | | |
| **SPECIES RICHNESS** | **128** | **45** | **33** | **48** | **2652** | **196** | **121** | **85** |
| **SPECIES ABUNDANCE** | **10** | **6** | **10** | **9** | **14** | **12** | **7** | **11** |

# Table 15. Avifauna Sampled in Hydrilla Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 103.19 | 118.75 | 157.96 | 231.76 | 258.38 | 161.31 | 159.71 | 205.17 |
| | | | | | | | | |
| **Arboreal Birds** | **7** | **14** | **27** | **32** | **3** | **50** | **41** | **83** |
| Blue-gray gnatchatcher | | | 1 | | | | | |
| Boat-tailed grackle | 7 | 12 | 10 | 25 | 3 | 15 | 9 | 4 |
| Common yellowthroat | | | | | | 3 | | |
| Eastern phoebe | | | 2 | | | | | |
| Fish crow | | | | 1 | | | | 9 |
| Marsh wren | | | 1 | | | | | |
| Palm warbler | | | 7 | 5 | | | | |
| Red-winged blackbird | | 2 | 6 | 1 | | 32 | 32 | 70 |
| **Aerial Feeding Birds** | **0** | **5** | **5** | **315** | **650** | **0** | **29** | **0** |
| Barn swallow | | 5 | | | | | 8 | |
| Northern rough-winged swallow | | | | | 1 | | 14 | |
| Tree swallow | | | 5 | 315 | 649 | | 7 | |
| **Aerial Searching Birds** | **8** | **19** | **2** | **23** | **1** | **9** | **19** | **14** |
| Belted kingfisher | 1 | | | 8 | | 3 | | |
| Black tern | 4 | 19 | | | | 2 | 19 | |
| Caspian tern | 1 | | | 5 | | 2 | | 2 |
| Forster's tern | | | | | | 2 | | |
| Gull | | | | | | | | 2 |
| Laughing full | 2 | | 1 | 4 | 1 | | | 9 |
| Purple martin | | | 1 | | | | | |
| Ring-billed gull | | | | 3 | | | | 1 |
| Ruddy duck | | | | 3 | | | | |
| **Floating and Diving Birds** | **633** | **276** | **8657** | **9065** | **7** | **61** | **324** | **1777** |
| American coot | 9 | 15 | 8238 | 8945 | 5 | 3 | 38 | 1649 |
| American anhinga | 3 | 12 | 1 | | | 8 | 12 | 3 |
| American white pelican | | | | | 2 | | | |
| Brown pelican | | | | 2 | | | | |
| Common loon | 3 | 12 | 1 | | | 8 | 12 | 3 |
| Common gallinule | 612 | 233 | 390 | 116 | | 42 | 147 | 111 |
| Double-crested cormorant | 1 | | | 1 | | | | 4 |
| Pied-billed grebe | 5 | 1 | 27 | 1 | | | 115 | 7 |
| Purple gallinule | | 3 | | | | | | |
| **Raptors and Vultures** | **4** | **0** | **0** | **5** | **0** | **0** | **0** | **6** |
| Bald eagle | 4 | | | | | | | |
| Northern harrier | | | | 1 | | | | 2 |
| Osprey | | | | | | | | 4 |
| Peregrine falcon | | | | 1 | | | | |
| Turkey vulture | | | | 3 | | | | |
| **Shorebirds** | **0** | **0** | **90** | **21** | **0** | **0** | **0** | **6** |
| Dunlin | | | 8 | 1 | | | | |
| Greater yellowlegs | | | 2 | 12 | | | | 1 |
| Least sandpiper | | | 8 | 3 | | | | 5 |
| Lesser yellowlegs | | | 72 | 5 | | | | |

## Table 15 - continued

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | | |
| **Surface Feeding Ducks** | **8** | **6** | **120** | **146** | **0** | **0** | **1** | **3** |
| Blue-winged teal | 1 | | 100 | 8 | | | | 1 |
| Fulvous whistling duck | | | | 80 | | | | |
| Ring-necked duck | 7 | 6 | 20 | 58 | | | 1 | 2 |
| **Long Legged Wading Birds** | **3** | **45** | **20** | **22** | **0** | **1** | **9** | **3** |
| Great blue heron | 3 | 3 | 12 | 12 | | 1 | 9 | 2 |
| Great egret | | 42 | 8 | 10 | | | | 1 |
| **Short Legged Wading Birds** | **29** | **129** | **526** | **116** | **0** | **4** | **60** | **44** |
| Glossy Ibis | 3 | | 7 | 9 | | | | 5 |
| Green-backed heron | 3 | 1 | 9 | 9 | | 2 | 1 | |
| King rail | | | | | | | 1 | |
| Little blue heron | | 1 | 19 | 13 | | | 11 | 14 |
| Least bittern | | 1 | | | | | | |
| Limpkin | | 4 | | | | | | |
| Snowy egret | 22 | 120 | 472 | 78 | | 2 | 41 | 23 |
| Tricolored heron | | 2 | 19 | 5 | | | 6 | 2 |
| White ibis | 1 | | | 2 | | | | |
| **SPECIES RICHNESS** | **692** | **494** | **9447** | **9745** | **661** | **125** | **483** | **1936** |
| **SPECIES ABUNDANCE** | **14** | **17** | **22** | **28** | **6** | **12** | **16** | **22** |

# Table 16a. Avifauna Sampled in Wet Mixed Grass Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 3.83 | 10.75 | 48.23 | 103.10 | 136.25 | 47.25 | 55.85 | 89.92 |
| | | | | | | | | |
| **Aroboreal Birds** | **40** | **1** | **7** | **7** | **20** | **50** | **3** | **265** |
| Boat-tailed grackle | 1 | | | 5 | 5 | 5 | 2 | 5 |
| Carolina wren | | | | | | 2 | | |
| Common yellowthroat | | | | | 1 | 3 | | 1 |
| Eastern meadowlark | 3 | | 1 | | | | 1 | |
| Northern cardinal | | | | | | 4 | | |
| Palm warbler | | | 1 | 2 | | | | 1 |
| Red-winged blackbird | 36 | 1 | 5 | | 14 | 36 | | 257 |
| Yellow-rumped warbler | | | | | | | | 1 |
| **Aerial Feeding Birds** | **1** | **0** | **2** | **100** | **263** | **0** | **4** | **0** |
| Barn swallow | | | 2 | | | | 4 | |
| Chimney swift | 1 | | | | | | | |
| Tree swallow | | | | 100 | 263 | | | |
| **Aerial Searching Birds** | **0** | **0** | **1** | **3** | **1** | **0** | **1** | **0** |
| Belted kingfisher | | | 1 | | | | 1 | |
| Caspian tern | | | | | 1 | | | |
| Forster's tern | | | | 3 | | | | |
| **Floating and Diving Birds** | **5** | **11** | **1** | **38** | **8** | **14** | **12** | **8** |
| American coot | | | | 27 | | | | 2 |
| American anhinga | | | 1 | | | 5 | 7 | 3 |
| Common gallinule | 5 | 11 | | 11 | 8 | 9 | 5 | 3 |
| **Raptors and Vultures** | | **5** | **2** | **2** | **1** | **0** | **1** | **1** |
| American kestrel | | | 1 | | | | | |
| American swallow-tailed kite | | 1 | | | | | | |
| Bald eagle | | 1 | | | | | | |
| Northern harrier | | | | 1 | | | | |
| Osprey | | | | | 1 | | 1 | |
| Peregrine falcon | | | | | | | | 1 |
| Turkey vulture | | 3 | 1 | 1 | | | | |
| **Shorebirds** | **5** | **5** | **0** | **0** | **0** | **0** | **0** | **0** |
| Black-necked stilt | 5 | 3 | | | | | | |
| Killdeer | | 2 | | | | | | |
| **Surface Feeding Ducks** | **2** | **0** | **0** | **0** | **7** | **1** | **0** | **157** |
| Blue-winged teal | | | | | | | | 1 |
| Mottled duck | 2 | | | | 2 | 1 | | |
| Ring-necked duck | | | | | 5 | | | 156 |
| **Long Legged Wading Birds** | **3** | **0** | **2** | **3** | **0** | **10** | **7** | **6** |
| Great blue heron | | | | 3 | | 1 | | |
| Great egret | | | 2 | | | 8 | 7 | 6 |
| Sandhill crane | 3 | | | | | 1 | | |
| **Short Legged Wading Birds** | **2** | **1** | **0** | **4** | **0** | **7** | **0** | **3** |
| Green-backed heron | | | | | | 1 | | |
| Little blue heron | | | | 2 | | 3 | | 2 |
| Snowy egret | | | | | | 1 | | |
| Tricolored heron | 1 | 1 | | 2 | | 2 | | 1 |
| White ibis | 1 | | | | | | | |
| **SPECIES RICHNESS** | **58** | **23** | **15** | **157** | **300** | **82** | **28** | **440** |
| **SPECIES ABUNDANCE** | **10** | **8** | **9** | **11** | **9** | **15** | **8** | **14** |

## Table 16b. Avifauna Sampled in Dry Torpedograss Habitat For All Sampling Events

| DATE | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
|---|---|---|---|---|---|---|---|---|
| Mean Water Depth | 1.60 | 4.25 | 54.60 | 104.15 | 132.38 | 46.50 | 46.35 | 78.11 |
| | | | | | | | | |
| **Arboreal Birds** | **29** | **2** | **18** | **26** | **9** | **49** | **1** | **10** |
| Boat-tailed grackle | 5 | 1 | 2 | 9 | 3 | 18 | 1 | 7 |
| Common yellowthroat | 2 | | | 4 | | 2 | | |
| Eastern meadowlark | | 1 | | | 1 | 1 | | |
| Fish crow | 1 | | | | | | | |
| Marsh wren | | | 5 | 4 | | | | |
| Northern cardinal | | | | | | 1 | | |
| Palm warbler | | | 2 | 6 | | | | 1 |
| Red-bellied woodpecker | | | | | | 1 | | |
| Red-winged blackbird | 21 | | 3 | 3 | 5 | 26 | | 1 |
| Savannah sparrow | | | 1 | | | | | |
| Sedge wren | | | 5 | | | | | 1 |
| **Aerial Feeding Birds** | **0** | **0** | **0** | **80** | **108** | **0** | **0** | **0** |
| Tree swAllow | | | | 80 | 108 | | | |
| **Aerial Searching Birds** | **0** | **0** | **1** | **1** | **0** | **0** | **0** | **1** |
| Belted kingfisher | | | 1 | 1 | | | | 1 |
| **Floating and Diving Birds** | **8** | **2** | **3** | **19** | **1** | **18** | **3** | **6** |
| American anhinga | | | | 2 | | | | 1 |
| Common loon | | | | | | 5 | 2 | 2 |
| Common gAllinule | 8 | 2 | 3 | 16 | 1 | 13 | 1 | 3 |
| Pied-billed grebe | | | | 1 | | | | |
| **Raptors and Vultures** | **0** | **0** | **2** | **2** | **1** | **0** | **1** | **2** |
| American kestrel | | | | | | | | 1 |
| Bald Eagle | | | 1 | | | | | |
| Northern harrier | | | 1 | 1 | 1 | | | |
| Osprey | | | | 1 | | | | |
| Turkey vulture | | | | | | | 1 | 1 |
| **Shorebirds** | **20** | **1** | **0** | **0** | **0** | **0** | **0** | **0** |
| Barn swallow | 4 | | | | | | | |
| Greater yellowlegs | | 1 | | | | | | |
| Killdeer | 1 | | | | | | | |
| Least sandpiper | 1 | | | | | | | |
| Lesser yellowlegs | 4 | | | | | | | |
| Stilt sandpiper | 10 | | | | | | | |
| **Surface Feeding Ducks** | **0** | **0** | **0** | **0** | **2** | **3** | **0** | **1246** |
| Blue-winged teal | | | | | | | | 22 |
| Mottled duck | | | | | 2 | 3 | | |
| Ring-necked duck | | | | | | | | 1224 |
| **Long Legged Wading Birds** | **0** | **0** | **3** | **0** | **0** | **8** | **0** | **5** |
| Great blue heron | | | | | | | | 1 |
| Great egret | | | 3 | | | 8 | | 4 |
| **Short Legged Wading Birds** | **0** | **0** | **0** | **0** | **0** | **1** | **0** | **2** |
| Least bittern | | | | | | 1 | | |
| Tricolored heron | | | | | | | | 2 |
| **SPECIES RICHNESS** | **57** | **5** | **27** | **128** | **121** | **79** | **5** | **1272** |
| **SPECIES ABUNDANCE** | **9** | **4** | **10** | **9** | **6** | **10** | **4** | **10** |

**Table 17. StatisticAlly Significant Relationships (ANOVA) Comparing Avifauna Bird Group Relative Abundance between Habitat within Lake Okeechobee Littoral Zone**

| Bird Groups | Model | | | Habitat Effect | Significant Relationships |
|---|---|---|---|---|---|
| | p-value | R-Square | df | p-value | |
| Arboreal Birds | 0.0001 | 0.5298 | 118 | 0.0001 | CAT,DE,DT,WMG>HY,WE & CAT>WMG |
| Aerial Feeding Birds | 0.0750 | 0.2635 | 113 | 0.0296 | None |
| Aerial Searching Birds | 0.0130 | 0.3002 | 114 | 0.0455 | DE,HY,WE,WMG>CAT,DT |
| Floating and Diving Birds | 0.0001 | 0.6947 | 118 | 0.0001 | HY>CAT,WE>DT,WMG>DE |
| Raptors and Vultures | 0.0001 | 0.7189 | 114 | 0.0001 | DE>CAT,DT,HY,WE,WMG |
| Shorebirds | 0.0001 | 0.4599 | 116 | 0.0001 | DT>WMG>CAT,DE,HY,WE |
| Surface Feeding Ducks | 0.0140 | 0.2991 | 118 | 0.0041 | DE,WE>CAT,DT,HY,WMG |
| Wading Birds Long Legged | 0.0001 | 0.4413 | 114 | 0.0001 | WMG>WE>CAT,DE,DT,HY |
| Wading Birds Short Legged | 0.0612 | 0.2569 | 119 | 0.0005 | None |

Significant results $P < 0.05$ For both Model and Effect
df = degrees of freedom
CAT= Cattail
HY=Hydrilla
DT= "Dry" Torpedograss
DE="Dry" Spikerush
WE="Wet" Spikerush
WMG= Wet Mixed Grass

## Table 18: StatisticAlly Significant Relationships (ANOVA) Between Avifauna Abundance For Water Depth and Season within Lake Okeechobee Littoral Zone Habitats

| Model | All Birds | Resident Birds | Migrant Birds | Arboreal Birds | Aerial Feeding Birds | Aerial Searcing Birds | Floating and Diving Birds | Raptors and Vultures | Shorebirds | Surface Feeding Ducks | Wading Birds Long Legged | Wading Birds Short Legged |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| p-value | 0.0001 | 0.0001 | 0.0001 | 0.1473 | 0.0028 | 0.0001 | 0.0001 | 0.0001 | 0.0018 | 0.0088 | 0.0001 | 0.0001 |
| R-Square | 0.7762 | 0.7138 | 0.8183 | 0.2792 | 0.3904 | 0.6628 | 0.8931 | 0..6902 | 0.3967 | 0.3616 | 0.5512 | 0.5261 |
| df | 120 | 116 | 115 | 121 | 120 | 115 | 115 | 117 | 121 | 121 | 120 | 120 |
| | | | | | | | | | | | | |
| **Effect: Water Depth** | | | | | | | | | | | | |
| p-value | 0.0001 | 0.0001 | 0.0010 | 0.1034 | 0.0001 | 0.5659 | 0.0001 | 0.4375 | 0.0598 | 0.6412 | 0.0071 | 0.0803 |
| Cattail | + | + | + | | + | | | | | | | |
| Hydrilla | - | - | - | | + | | - | | | | - | |
| Dry Torpedograss | | | | | + | | | | | | | |
| Dry Spikerush | | | | | | | | | | | | |
| Wet Spikerush | | | | | | | | | | | - | |
| Wet Mixed Grass | | | | | + | | | | | | | |
| | | | | | | | | | | | | |
| **Effect: Season** | | | | | | | | | | | | |
| p-value | 0.0001 | 0.0001 | 0.0001 | 0.0698 | 0.9661 | 0.0578 | 0.0001 | 0.0034 | 0.0126 | 0.0622 | 0.0006 | 0.0004 |
| Cattail | | WET+ | | | | | | | | | | WET+ |
| Hydrilla | DRY+ | DRY+ | DRY+ | | | | DRY+ | | DRY+ | | DRY+ | DRY+ |
| Dry Torpedograss | | | | | | | | DRY+ | | | | |
| Dry Spikerush | | | | | | | | DRY+ | | | | |
| Wet Spikerush | | | | | | | | DRY+ | | | | |
| Wet Mixed Grass | | | | | | | | | | | | |

Significant results $p < 0.05$

df = degrees of freedom

"+" = positive relationship

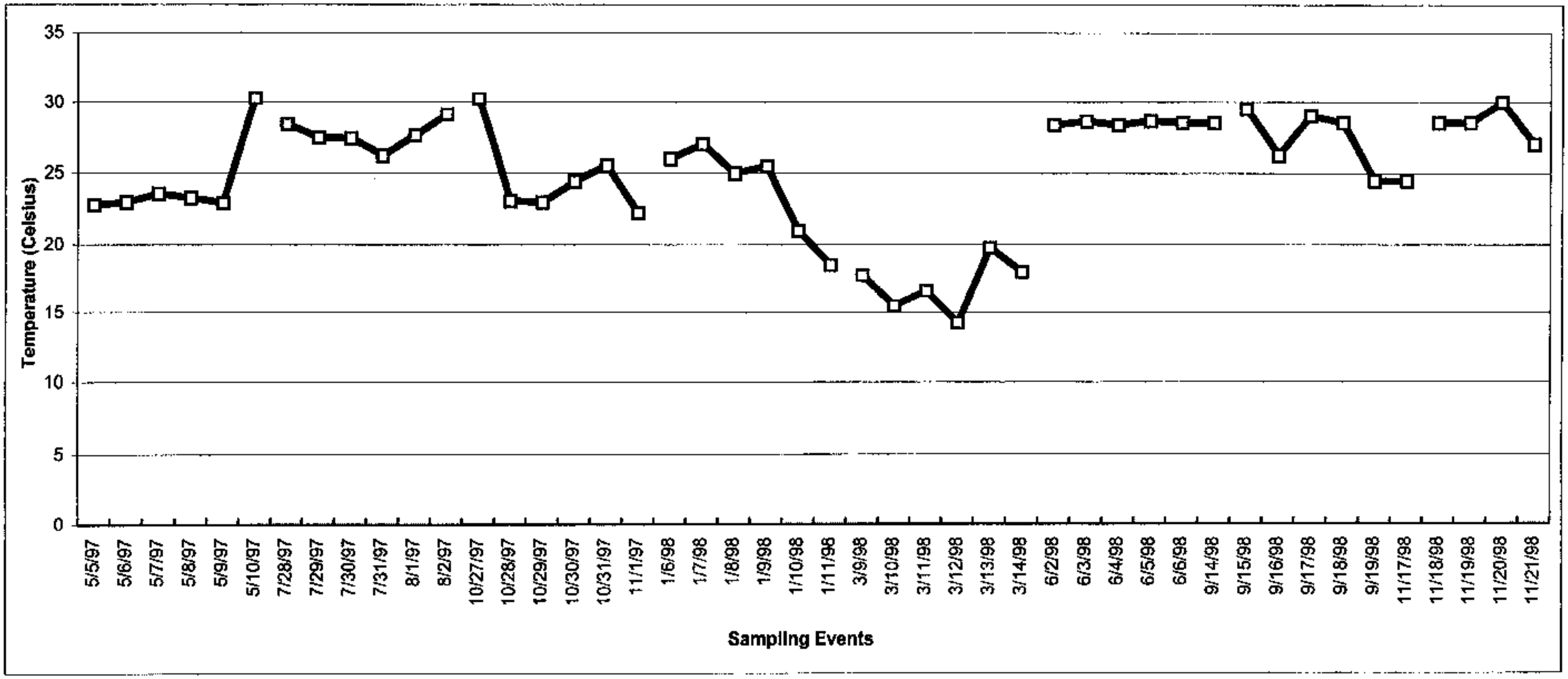
"-" = negative relationship

WET = Wet Season (May-Septembe)

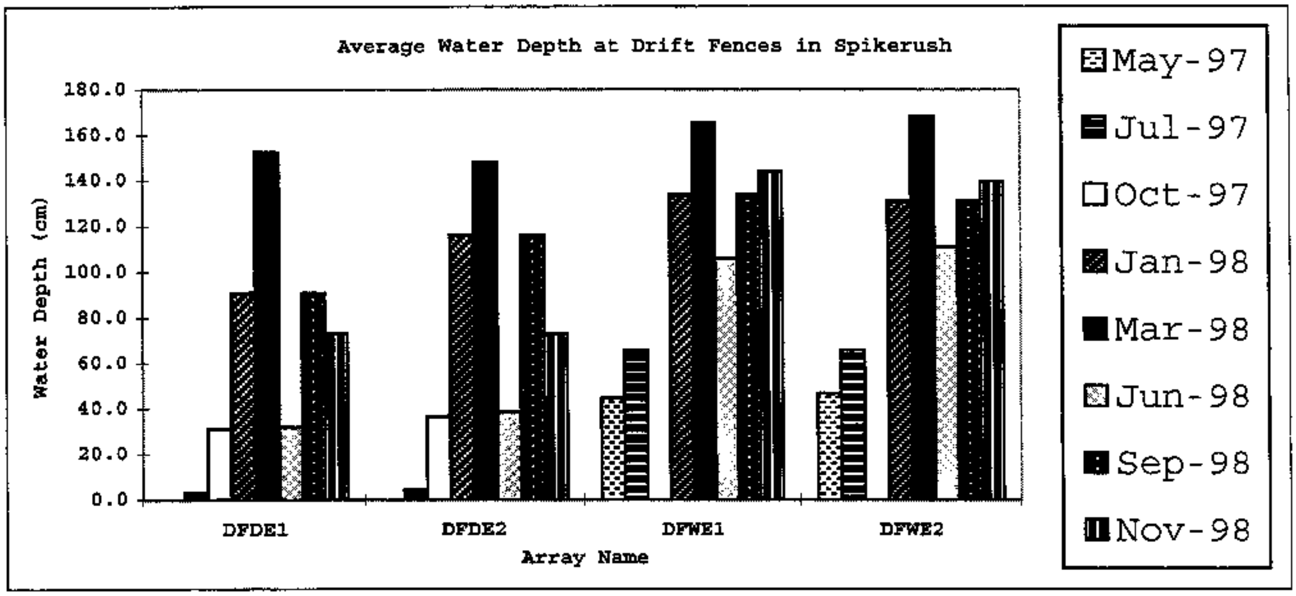
DRY = Dry Season (Ocober-April)

# GRAPHS

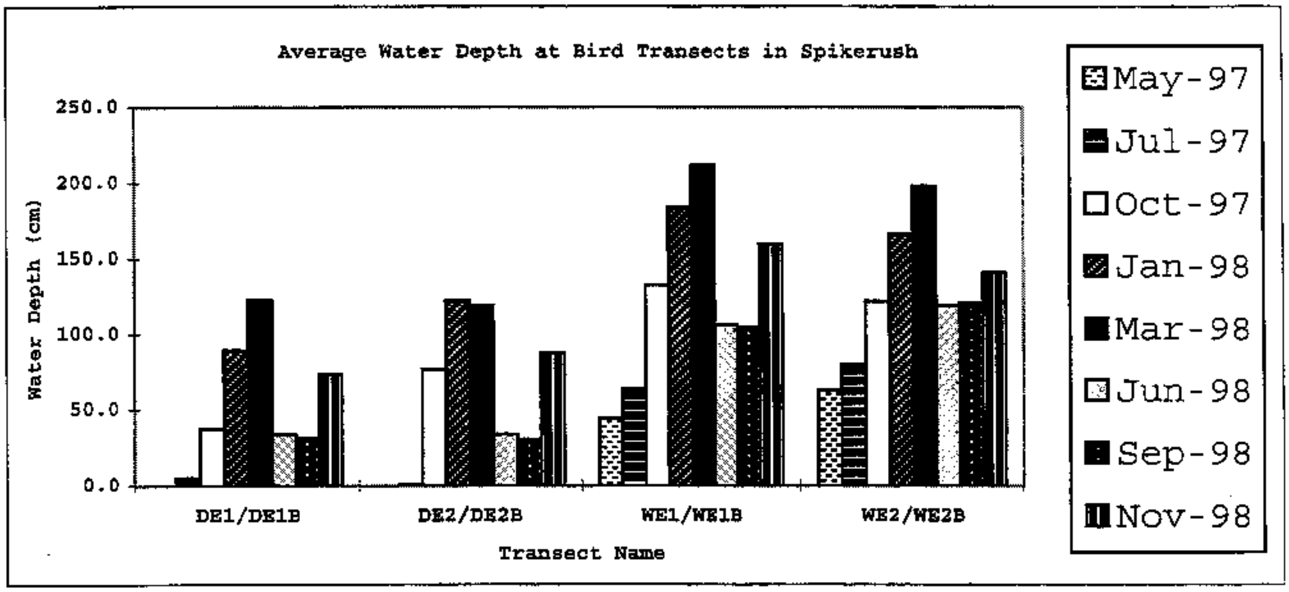
## Graph 1. Average Daily Air Temperatures Recorded For Each Day Sampled



## Graph 2. Water Depths Recorded in Spikerush For All Events

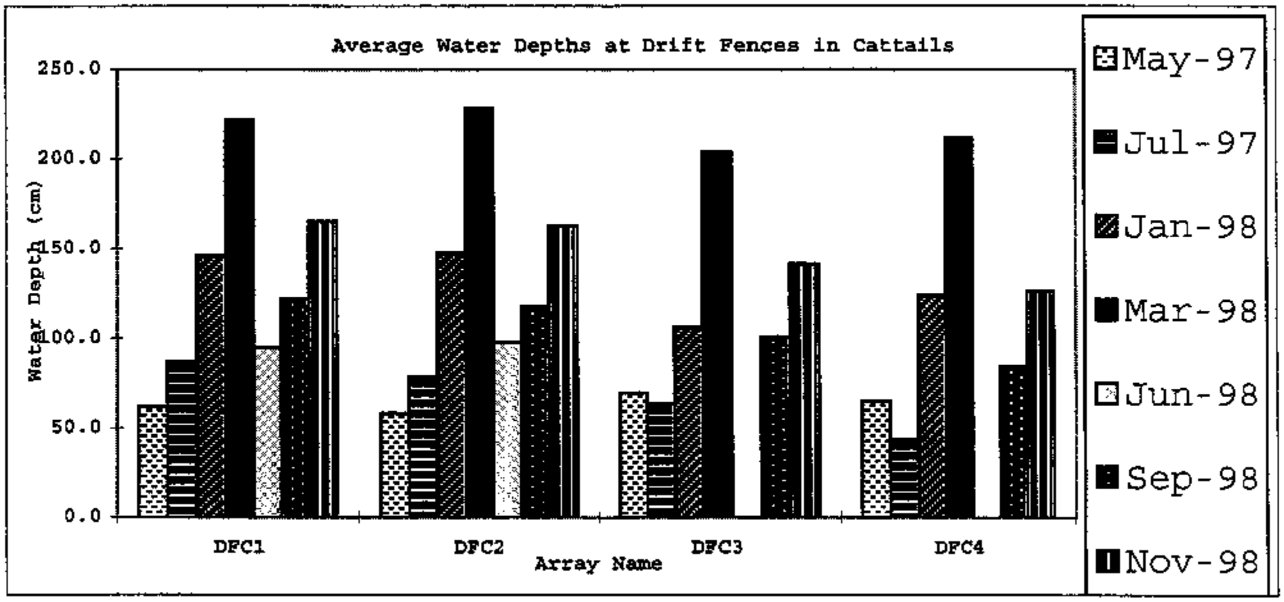



For May 1997, water depth For DFDE1 and DFDE2 was zero.
For October 1997, no data collected at DFWE1 & DFWE2 due to inclement weather

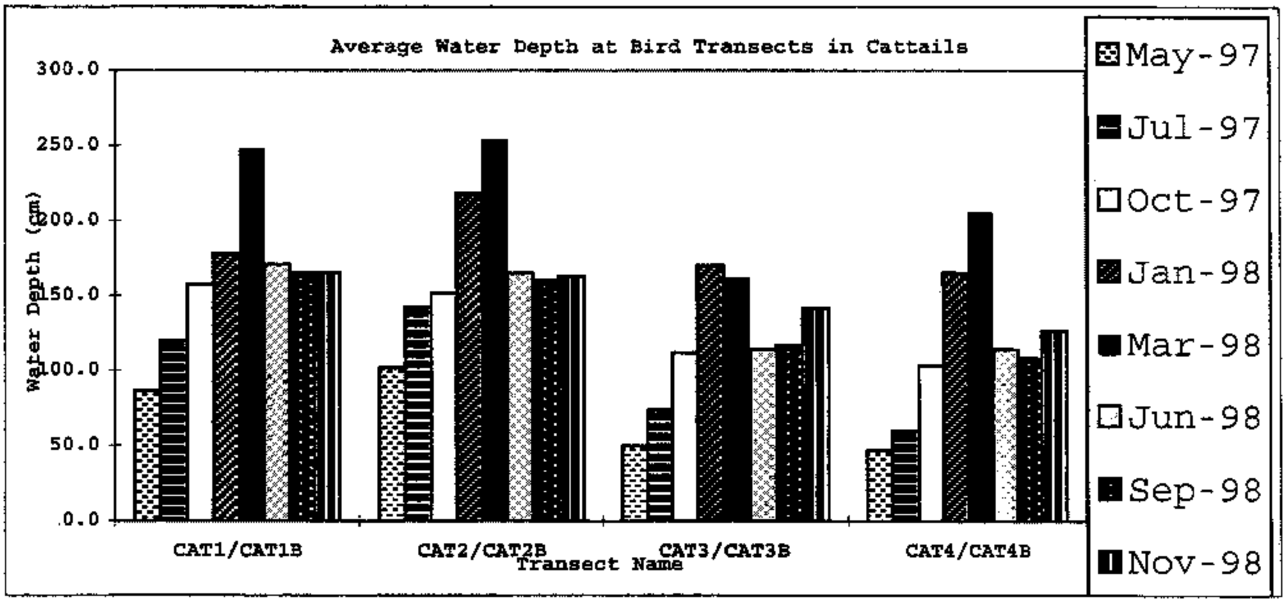



For May 1997, water depth For DE1/DE1B and DE2/DE2B was zero.

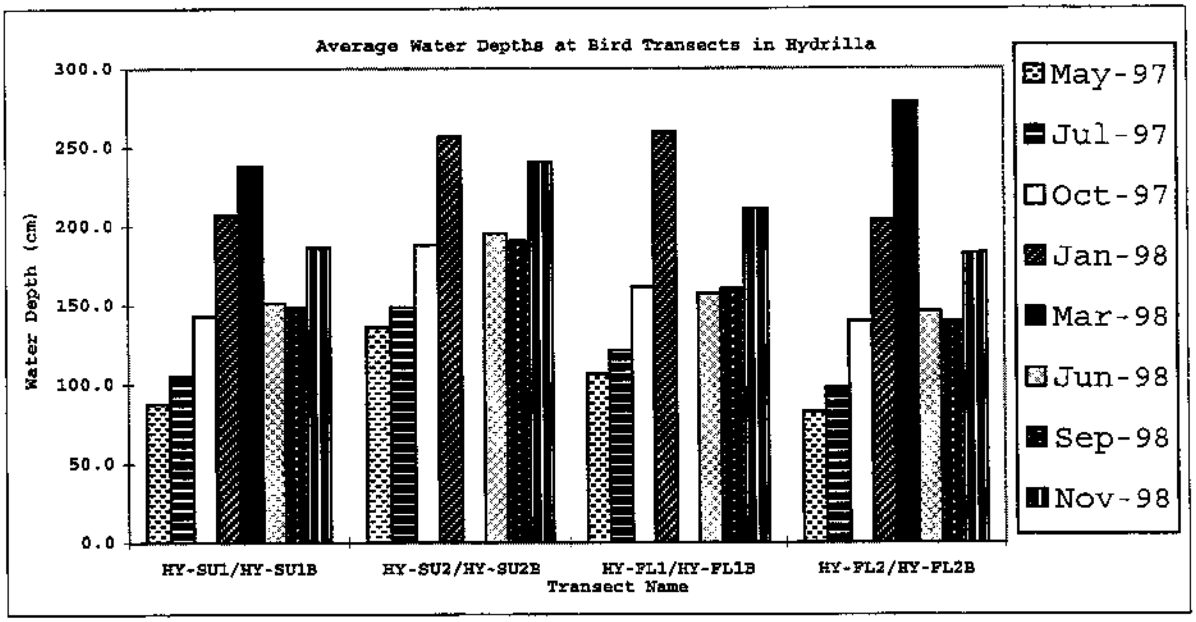
# Graph 3. Water Depths Recorded in Cattails For All Events




No data collected in cattail during October 1997 due to inclement weather.

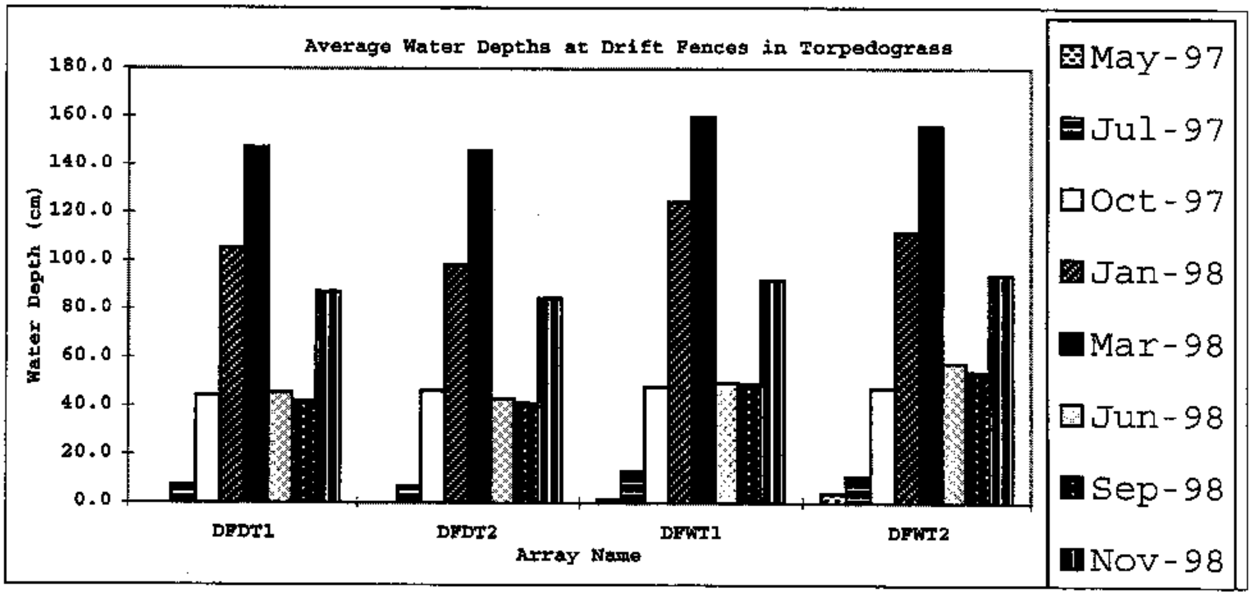


## Graph 4. Water Depths Recorded in Hydrilla For All Events

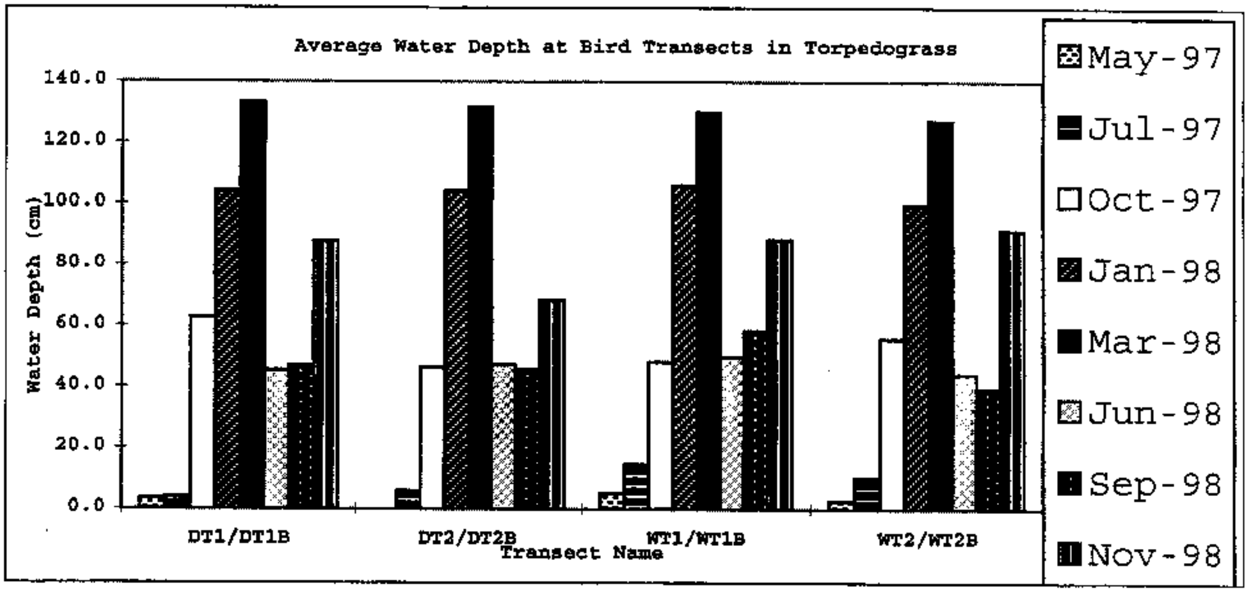



No sampling occurred in hydrilla during March 1998 due to inclement weather.

## Graph 5. Water Depths Recorded in Torpedograss For All Events

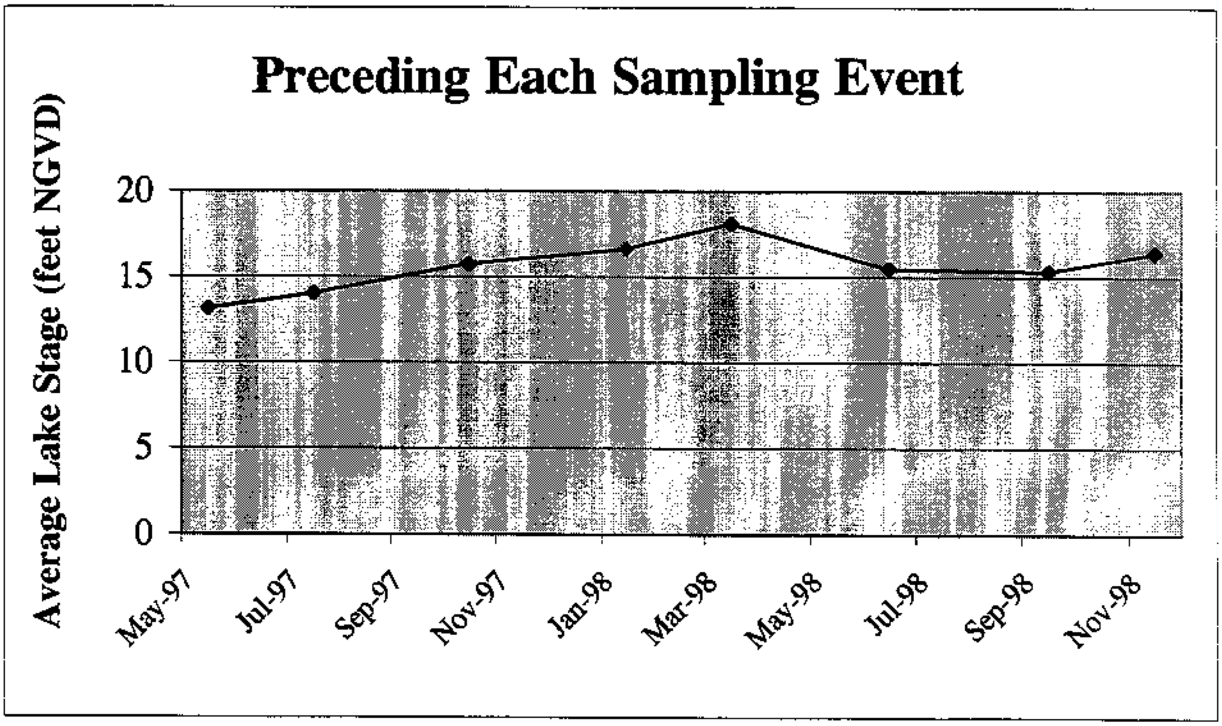


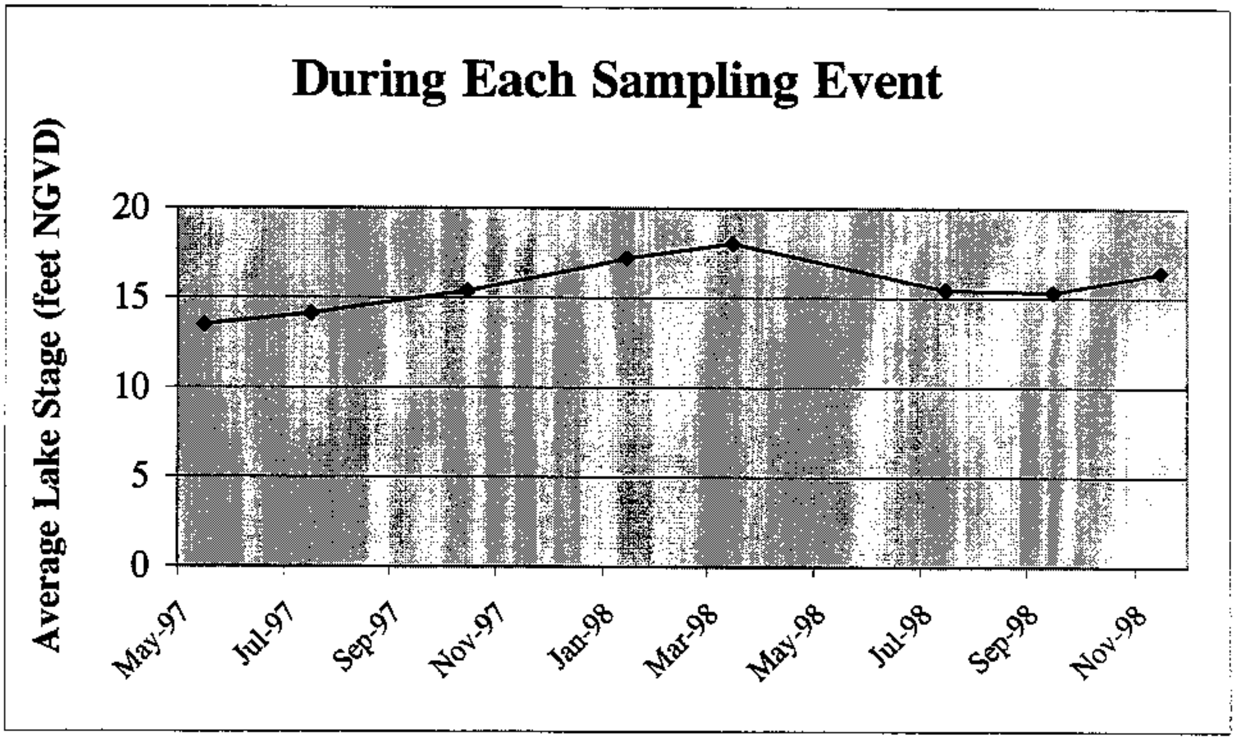

For May 1997, water depth For DFDT1 and DFDT2 was zero.




For May 1997, water depth For DT2/DT2B was zero.

**Graph 6. Average Lake Stage Recorded at S-77 Lock, Moore Haven, Florida, For The 21 Days Preceding and During Each Sampling Event**



# APPENDIX A

## Representative Photos of Study Area

REPRESENTATIVE PHOTOS WITHIN SPIKERUSH COMMUNITY

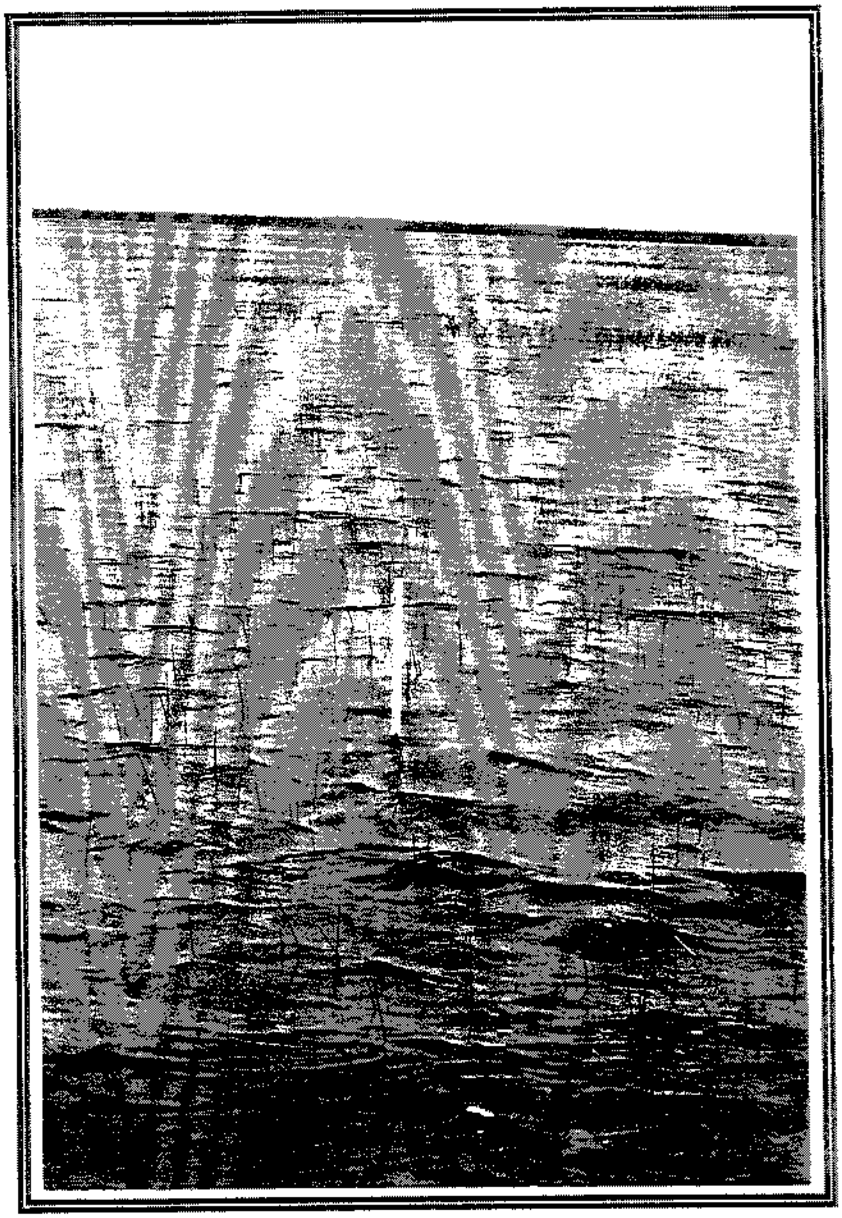


Photo 1. Spikerush Community - 10 March 1998; Water Depth = 196 cm

REPRESENTATIVE PHOTOS WITHIN SPIKERUSH COMMUNITY

Photo 2. Drift Fence Installation Within Spikerush Community - 8 May 1997
Water Depth = 45.09 cm

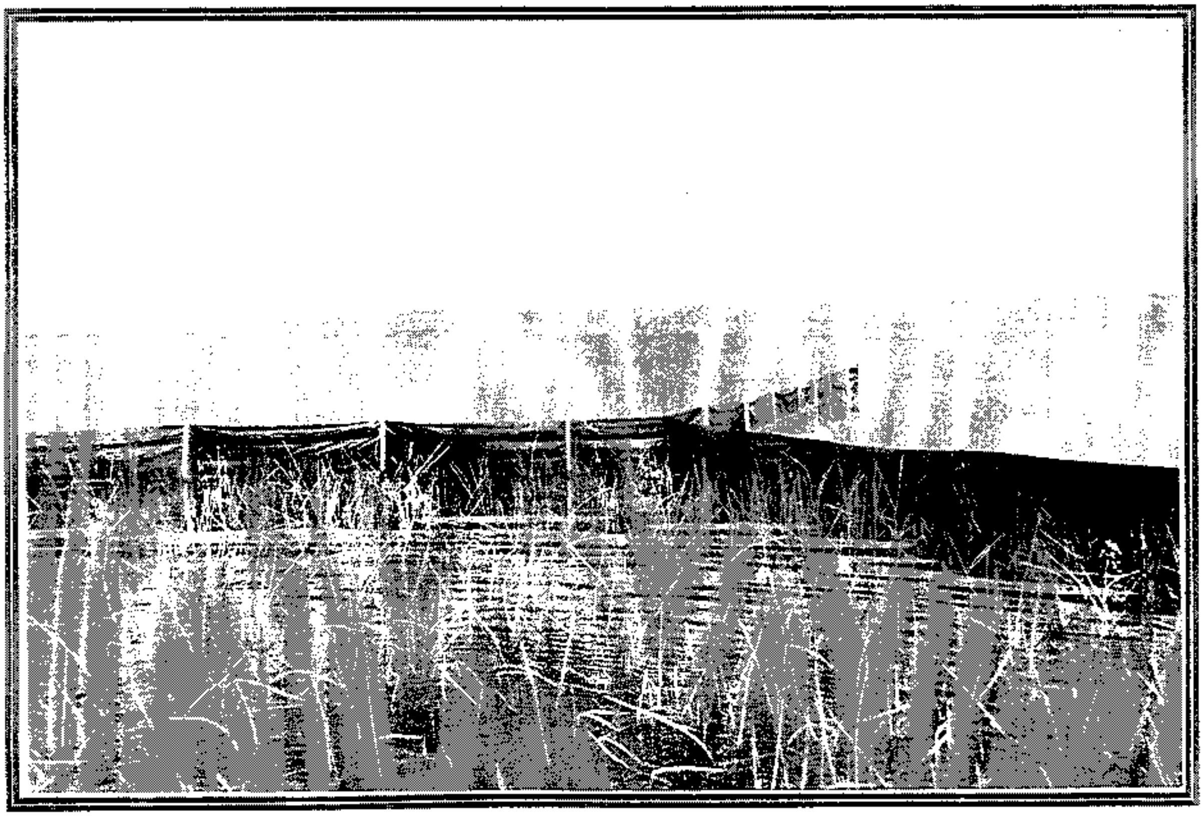


Photo 3. Drift Fence Within Spikerush Community - 8 May 1997
Water Depth = 45.09 cm

REPRESENTATIVE PHOTOS WITHIN SPIKERUSH COMMUNITY

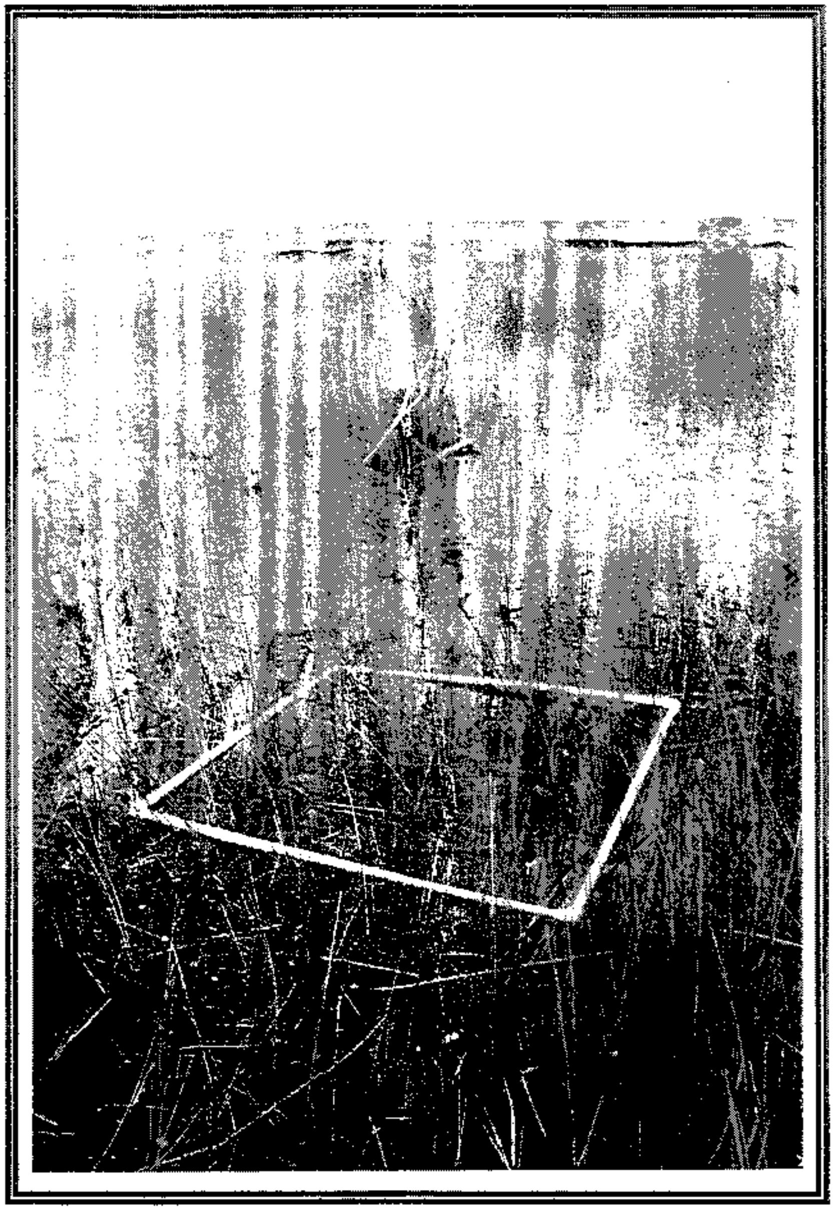


Photo 4. Sampling Quadrat within Spikerush Community - 14 September 1998; Water Depth = 46 cm

REPRESENTATIVE PHOTOS WITHIN CATTAIL COMMUNITY

Photo 5. Drift Fence Installation Within Cattail Community - 8 May 1997; Water Depth = 60.33 cm

Photo 6. Edge of Cattail Community with wintering American Coots in foreground - 9 January 1998; Water Depth = 165.1 cm

REPRESENTATIVE PHOTOS WITHIN CATTAIL COMMUNITY

Photo 7. Sampling Quadrat within Cattail Community - 14 September 1998; Water Depth = 68 cm

Photo 8. Hydrilla Community; Week of 5 -8 May 1997; Water Depth = 81.28 - 137.16 cm

Photo 9. Hydrilla Community - 27 October 1997; Water Depth = 163.83 cm

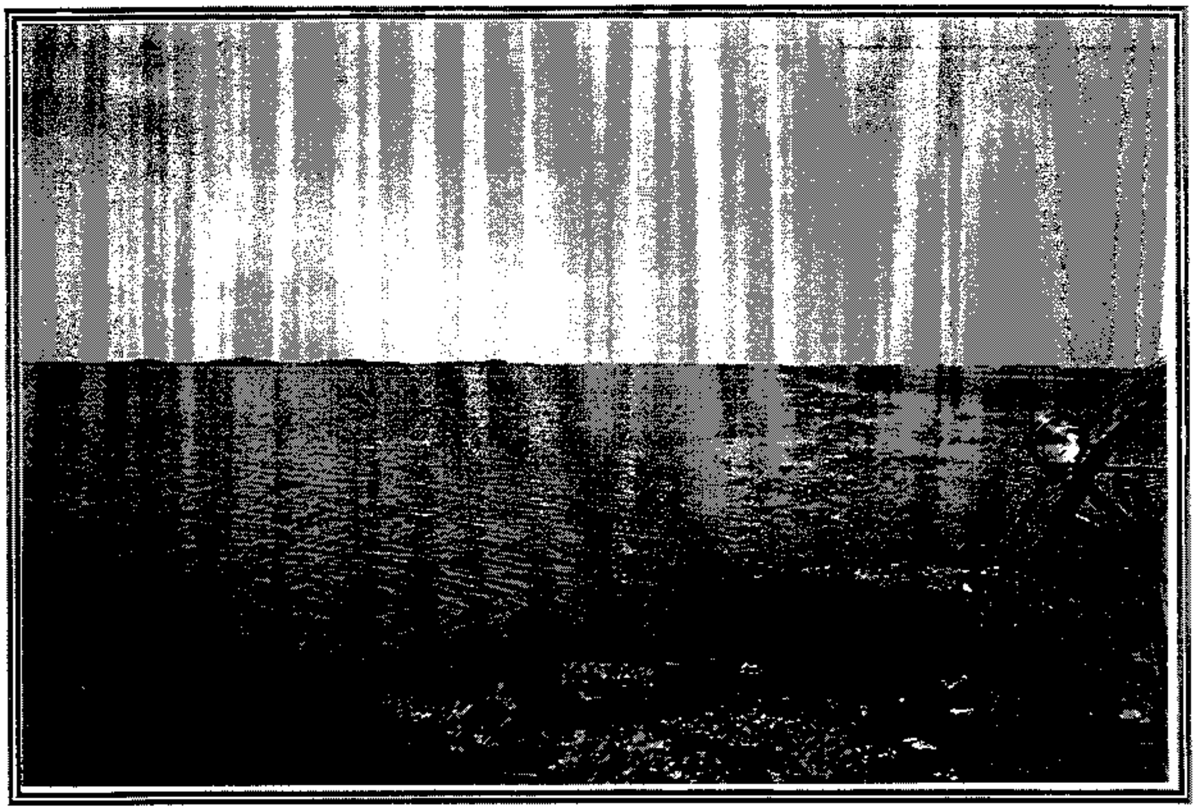


Photo 10. Hydrilla Community - 5 May 1997; Water Depth = 45.09 cm

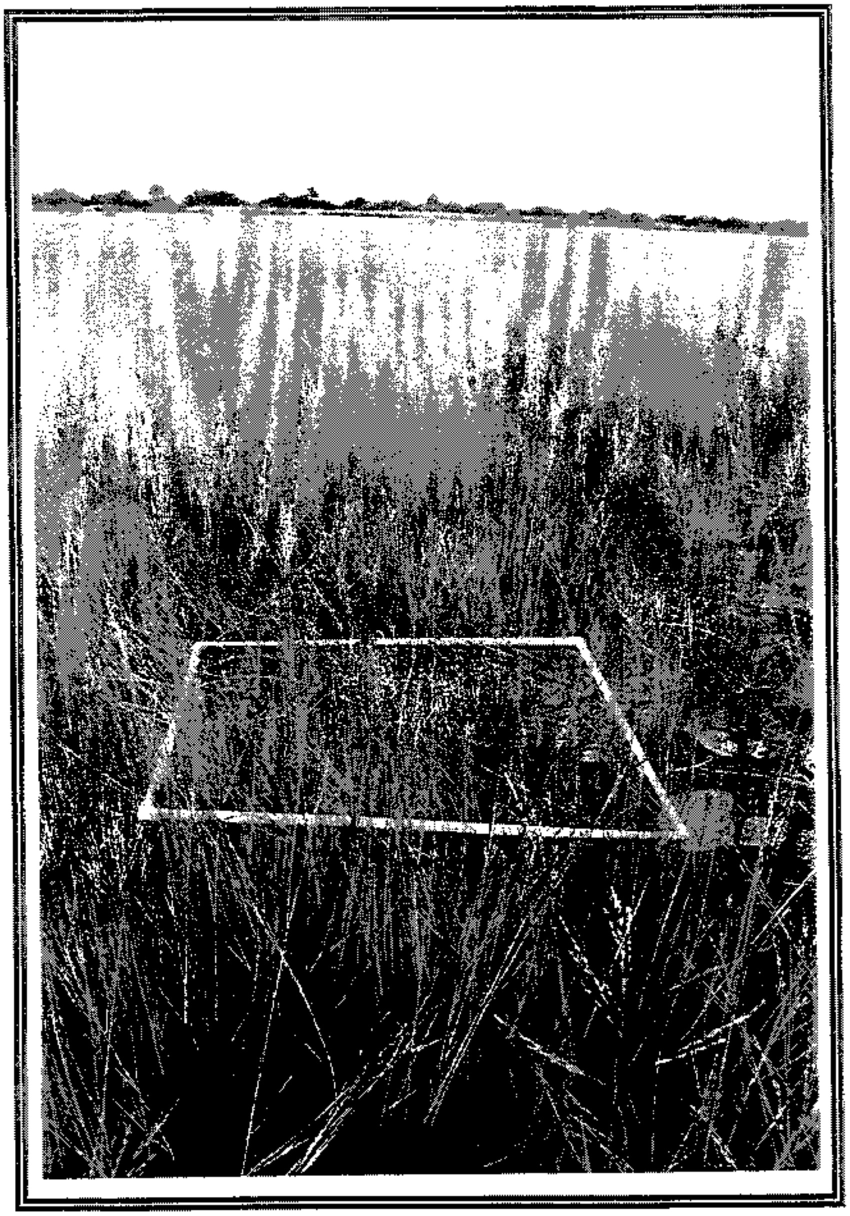


Photo 11. Torpedograss Community - 16 September 1998; Water Depth = 25 cm

# APPENDIX B

## Maps of Sampling Locations

# APPENDIX C

## Incidentally Trapped Fauna Data

**Fish Sampled via Drift Fence for Spikerush Habitats for All Sampling Events**

| | SPIKERUSH | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SPECIES | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Bluegill (*Lepomis macrochirus*) | | 3 | | | | 1 | 15 | 4 |
| Blue-spotted sunfish (*Enneacanthus gloriosus*) | 14 | 8 | 11 | | | 17 | 18 | 7 |
| Brown bull head (*Ictalurus nebulosus*) | | | | | | | | 2 |
| Florida flagfish (*Jordanella floridae*) | | | 4 | 3 | | 4 | | |
| Golden topminnow (*Fundulus chrysotus*) | | | 6 | 8 | 5 | 1 | 1 | |
| Largemouth bass (*Micropterus salmoides*) | 3 | | | | | 2 | | |
| Least killifish (*Heterandria formosa*) | 7 | 5 | 1 | 3 | 1 | 1 | 1 | |
| Mosquitofish (*Gambusia affinis*) | | | | | | | 13 | |
| Redear sunfish (*Lepomis microlophus*) | 42 | 16 | 15 | 2 | 1 | 30 | 4 | 1 |
| Sailfin molly (*Poecilia latipinna*) | | | | | | 2 | | |
| Spotted gar (*Lepisosteus oculatus*) | | 1 | | 1 | | | | |
| Taillight shiner (*Notropis maculatus*) | 4 | | | | 1 | 2 | | |
| Warmouth (*Lepomis gulosa*) | | 1 | | | | 6 | | |
| Species Abundance | 70 | 34 | 37 | 17 | 8 | 66 | 52 | 14 |
| Species Richness | 5 | 6 | 5 | 5 | 4 | 10 | 6 | 4 |

## Fish Sampled via Drift Fence for Cattail Habitats for All Sampling Events

| | CATTAIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SPECIES | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Bluegill (*Lepomis macrochirus*) | | | | | | | | |
| Blue-spotted sunfish (*Enneacanthus gloriosus*) | | 2 | | | | | | |
| Brown bull head (*Ictalurus nebulosus*) | | | | | | | 2 | 1 |
| Florida flagfish (*Jordanella floridae*) | | | | | | | | |
| Golden topminnow (*Fundulus chrysotus*) | | | | 1 | | | | |
| Largemouth bass (*Micropterus salmoides*) | | | | | | | | 1 |
| Least killifish (*Heterandria formosa*) | 3 | 6 | | | | | | |
| Mosquitofish (*Gambusia affinis*) | | 2 | | | | 2 | 7 | 8 |
| Redear sunfish (*Lepomis microlophus*) | | 1 | | | | | | |
| Sailfin molly (*Poecilia latipinna*) | | 3 | | | | 3 | 6 | 10 |
| Spotted gar (*Lepisosteus oculatus*) | | | | | | 1 | 1 | |
| Taillight shiner (*Notropis maculatus*) | | | | | | | | |
| Warmouth (*Lepomis gulosa*) | | | | | | | | |
| **Species Abundance** | **3** | **14** | * | **1** | **0** | **6** | **16** | **20** |
| **Species Richness** | **1** | **5** | * | **1** | **0** | **3** | **4** | **4** |

* No sampling occured for October 1997 in cattails due to inclement weather.

## Fish Sampled via Drift Fence for Torpedograss Habitats for All Sampling Events

| | TORPEDOGRASS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| Bluegill (*Lepomis macrochirus*) | | | | | | 1 | 4 | 2 |
| Blue-spotted sunfish (*Enneacanthus gloriosus*) | | | 40 | 9 | | 29 | 18 | 11 |
| Brown bull head (*Ictalurus nebulosus*) | | | | | | 9 | 1 | |
| Florida flagfish (*Jordanella floridae*) | | 5 | | | | 68 | | |
| Golden topminnow (*Fundulus chrysotus*) | | | 7 | | 2 | 8 | | |
| Largemouth bass (*Micropterus salmoides*) | | | | | | 1 | 1 | |
| Least killifish (*Heterandria formosa*) | | | 2 | | 2 | | | |
| Mosquitofish (*Gambusia affinis*) | | 2 | | | | | 11 | 2 |
| Redear sunfish (*Lepomis microlophus*) | | | 29 | 4 | 1 | 25 | 11 | 12 |
| Sailfin molly (*Poecilia latipinna*) | | | | | | 1 | | |
| Spotted gar (*Lepisosteus oculatus*) | | | | | | 1 | 1 | |
| Taillight shiner (*Notropis maculatus*) | | | | | | 1 | | |
| Warmouth (*Lepomis gulosa*) | | | | | | 5 | | |
| **Species Abundance** | 0 | 7 | 78 | 13 | 5 | 149 | 47 | 27 |
| **Species Richness** | 0 | 2 | 4 | 2 | 3 | 11 | 7 | 4 |

**Macroinvertebrates Sampled via Drift Fence for Spikerush Habitats for All Sampling Events**

| | | SPIKERUSH | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| (*Bellostomatid*) beetles | 11 | | | | | 1 | 22 | 1 |
| (*Dityscid*) beetles | 5 | | | | | | | |
| Apple snails(*Pomacea paludosa*) | 33 | 222 | 25 | | | 51 | | 8 |
| Crayfish (*Procambarus* spp.) | 4 | 5 | 2 | 3 | | 31 | 10 | 5 |
| Dragonfly nymph | | | | | | 9 | 2 | |
| Grass shrimp (*Paleomonetus paludosus*) | | 1 | 4 | | 1 | 16 | 10 | 1 |
| Leech | | | | | | | 1 | |
| Millipede (*Julus* spp.) | 2 | | | | | | | |
| Mole crickets | | | | | | | | |
| Water scorpion | | | | | | 1 | 2 | |
| Wolf spiders | 6 | 1 | | | | | | |
| **Species Abundance** | **61** | **229** | **31** | **3** | **1** | **109** | **47** | **15** |
| **Species Richness** | **6** | **4** | **3** | **1** | **1** | **6** | **6** | **4** |

## Macroinvertebrates Sampled via Drift Fence for Cattial Habitats for All Sampling Events

| | CATTAIL | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SPECIES** | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| *(Bellostomatid)* beetles | 8 | 2 | | | | 3 | 7 | 5 |
| *(Dityscid)* beetles | | 1 | | | | 1 | | |
| Apple snails(*Pomacea paludosa*) | 11 | 17 | | | | 1 | | |
| Crayfish (*Procambarus* spp.) | 10 | 11 | | | | | | |
| Dragonfly nymph | | | | | | | | |
| Grass shrimp (*Paleomonetus paludosus*) | | 1 | | | | | | |
| Leech | | | | | | | | |
| Millipede (*Julus* spp.) | | | | | | | | |
| Mole crickets | | | | | | | | |
| Water scorpion | | | | | | | | 1 |
| Wolf spiders | | | | | | | | |
| **Species Abundance** | **29** | **32** | ***** | **0** | **0** | **5** | **7** | **6** |
| **Species Richness** | **3** | **5** | ***** | **0** | **0** | **3** | **1** | **2** |

* No sampling occured for October 1997 in cattails due to inclement weather.

## Macroinvertebrates Sampled via Drift Fence for Torpedograss Habitats for All Sampling Events

| | TORPEDOGRASS | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| SPECIES | May-97 | Jul-97 | Oct-97 | Jan-98 | Mar-98 | Jun-98 | Sep-98 | Nov-98 |
| (*Bellostomatid*) beetles | | 1 | | 2 | | 34 | 31 | 5 |
| (*Dityscid*) beetles | | | | | | | | |
| Apple snails(*Pomacea paludosa*) | | 1 | 21 | | | 6 | | |
| Crayfish (*Procambarus* spp.) | | | 1 | 2 | | 24 | 13 | 18 |
| Dragonfly nymph | | | | | | 4 | | |
| Grass shrimp (*Paleomonetus paludosus*) | | | 2 | | 2 | | | |
| Leech | | | | | | | | |
| Millipede (*Julus* spp.) | | | | | | | | |
| Mole crickets | 6 | | | | | | | |
| Water scorpion | | | | | | | 2 | |
| Wolf spiders | 7 | 2 | | | | | | |
| **Species Abundance** | 13 | 4 | 24 | 4 | 2 | 68 | 46 | 23 |
| **Species Richness** | 2 | 3 | 3 | 2 | 1 | 4 | 3 | 2 |

# ANNEX A

# FISH and WILDLIFE COORDINATION ACT REPORT

April 16, 1999

OFFICE OF ENVIRONMENTAL SERVICES
BRADLEY J. HARTMAN, DIRECTOR
FARRIS BRYANT BUILDING
620 South Meridian Street
Tallahassee, FL 32399-1600
(850) 488-6661
SUNCOM 278-6661
FAX (850) 922-5679
TDD (850) 488-9542

Colonel Joe R. Miller
District Engineer
U.S. Army Corps of Engineers
P.O. Box 4970
Jacksonville, Florida 32232-0019

Re: Lake Okeechobee Regulation Schedule Study, Multiple Counties

Dear Colonel Miller:

The Office of Environmental Services of the Florida Game and Fresh Water Fish Commission (GFC) has reviewed the proposed set of regulation schedules for Lake Okeechobee, and has consulted with the GFC's Division of Fisheries staff who manages the lake fishery. We have sent two Planning Aid Letters, one cosigned with the U.S. Fish and Wildlife Service and dated 24 September 1997, and another under GFC letterhead and dated 20 May 1998. This letter constitutes our preliminary Fish and Wildlife Coordination Act (FWCA) report, as provided for under §662(b) of the FWCA of 1973. Our input is based on information provided in four reports (see the attachment) primarily by the local sponsor, the South Florida Water Management District (SFWMD).

**Background**

The alternatives under consideration are Run 25, Run 22AZE, COE, HSM, and WSE. Run 25 is the current schedule, and has been in place since 1992. It is characterized by a 15.62- to 16.75-foot schedule, with multiple operational zones above that until the maximum release rates are reached at water levels of 17.0 to 18.5 feet. Run 22AZE is a derivative of a schedule (Run 22) that was considered, but not adopted, in the early 1990s on the basis of recommendations by the Lake Okeechobee Littoral Zone Technical Group in 1988. The basis of this recommendation was the fact that the schedule would allow the littoral zone to dry periodically, a condition necessary to maintain its vegetative structure. COE and HSM, developed by the U.S. Army Corps of Engineers and the SFWMD, respectively, have been introduced more recently. COE is essentially the same as Run 25, but with a slightly lower (14.5 to 16.0 feet) schedule. HSM, with a 14.0- to 16.75-foot schedule, introduces the concept of weather forecasting by adjusting releases for each zone based in part on a six-month inflow forecast. It also allows pulse releases to the estuaries when conditions are very wet. Finally, WSE is the newest of the proposed alternatives, having been introduced by SFWMD after the comparison of model output for the other alternatives was released in draft version. It represents an attempt to integrate the benefits of those other schedules. Like HSM, it relies on climate forecasting, and is therefore more flexible than are previously proposed schedules; it also incorporates HSM's pulse releases to the estuaries. Notably from the standpoint of maintaining a healthy littoral zone, it also allows the lake levels to fall to 13.5 feet, as would Run 22AZE.

The report titled *Simulation of Alternative Operational Schedules for Lake Okeechobee* (final report dated 7 May 1998) uses output from the South Florida Water Management Model to make predictive comparisons among the alternative schedules for a number of performance measures that were developed by an interagency team of biologists and planners in 1996. The performance measures include considerations of conditions that would affect the lake's littoral zone, the St. Lucie and Calooshahatchee estuaries, the Water Conservation Areas, and Everglades National Park. Performance measures for water supply for the Everglades Agricultural Area and the lower east coast (Palm Beach, Broward, and Miami-Dade counties) were also developed. These performance measures were used to evaluate the effects of each of the alternatives both on the natural system in and downstream of the lake, and on consumers who depend on the lake as a source of water. For each performance measure, model output was used to simulate a hypothetical 1990 base condition and a hypothetical 2010 future condition (i.e., model runs of the 31-year period of rainfall record, assuming 1988-1990 infrastructure, and model runs of the same period of record, assuming demands in 2010, respectively).

Unfortunately, it is not possible at this time to compare the performance of WSE with the other schedules for all of the performance measures. The output for Run 25, Run 22AZE, COE, and HSM was produced in a unified set of graphs for the draft report, which was released before WSE was introduced. Rather than revise the original figures to incorporate WSE, the final report tacked on an additional section that only compared the output for WSE with Run 25. Although it was possible to transcribe some of the WSE information onto the graphs for the other alternatives, the output for a number of important performance measures (e.g., the bar-and-whisker diagrams for the littoral zone) was presented at a different scale for WSE than it was for the original set of alternatives. In addition, it was not possible to compare the stage hydrographs and, to a lesser extent, the stage duration curves due to the fact that they are compressed into an 8-inch by 11-inch page format. This was a particular problem in terms of our ability to read the stage hydrographs that depict the wading bird "windows." Our 20 May 1998 Planning Aid Letter had requested that these difficulties be resolved, but as of this time we have not received the output in a form that would allow us to make a more thorough comparison. The attachment provides a breakdown of the performance measures that we were able to use to compare WSE with alternatives other than Run 25.

**Comparison of Run 22AZE and WSE**

The focus of our report is a comparison of WSE and Run 22AZE. HSM was not as closely reviewed since WSE is considered to be an improvement over HSM, and COE was not closely reviewed due to the lack of a sufficiently low schedule to benefit the lake's littoral zone. Both WSE and Run 22AZE appear to be clear improvements over Run 25; however, neither WSE nor Run 22AZE is obviously better in terms of protecting the lake's littoral zone, the estuaries, or the Everglades. The primary difference between the two schedules appears to be WSE's greater ability to satisfy water demands within the Everglades Agricultural Area.

Lake Okeechobee. The stage duration curves and the number of undesirable stage events for the lake indicates that WSE would result in somewhat higher lake stages than would Run 22AZE, but WSE would not result in as many instances of extremely low levels (i.e., below 12 feet NGVD), particularly as modeled for the 2010 condition. The extent to which the difference in output is significant, given the limits of the model itself, is not clear; however, the fact that both schedules would allow lake levels to fall to 13.5 feet NGVD, as opposed to 15.5 feet under Run 25, would greatly benefit the littoral zone by allowing it to dry periodically. These periodic dryouts are necessary for the germination of graminoid species that provide the community structure that support the fish and wildlife that depend on a healthy littoral zone.

St. Lucie and Caloosahatchee estuaries. Run 22 AZE appears to produce generally slightly better results in terms of amount and number of discharges from the lake to the estuaries, number of times that the salinity envelope criteria would not be met, and times that the high-discharge criteria (1,600 cfs and 2,500 cfs for the St. Lucie estuary; 2,500 cfs and 4,500 cfs for the Caloosahatchee estuary) would be exceeded. On the other hand, both estuaries suffer from discharge volumes that are affected by far greater problems than can be solved through a regulation schedule for Lake Okeechobee, and differences in model output are swamped by the larger problem of needing to provide alternative methods of water storage on a regional scale. For example, the best performance of any alternative for meeting the high-discharge criteria for the St. Lucie estuary is 540% of the target (Run 22AZE for meeting the criterion for 2,500 cfs under the 2010 condition) and 255% of the target for the Caloosahatchee estuary (Run 22AZE for the 2,800 cfs under the 2010 condition). The need to reduce discharges and attenuate flows is an issue that is currently being addressed through the Central and South Florida Comprehensive Review Study (the "Restudy"). Until the Restudy components that would alleviate these problems come on line, we anticipate that the difference between WSE and Run 22AZE would be minimal in terms of impacts on the estuaries.

Water Conservation Areas (WCAs). The only types of model output that we could use to compare the performance of all alternatives in the WCAs were (1) the frequency and percent of time that water levels would fall below ground for over 30 days and (2) the mean number of matches with the Natural System Model for a 31-year period of record. The first of these performance measures was chosen on the basis of observation that damaging muck fires in the WCAS appear to be correlated with groundwater levels falling lower than a foot below ground. The model output for this performance measure indicates that there is very little difference between Run 22AZE and WSE with regard to low-water impacts to the WCAs.

The second of the two performance measures is based on the best available hydrologic model of predrainage conditions at the individual model cells where water gages are currently located. At the time that the performance measures were developed in 1996, this approach seemed reasonable; however, a review of certain features of the Natural System Model (and, by extension, the South Florida Water Management Model) by the U.S. Geological Survey since then indicates that predictions of water conditions on a cell-by-cell basis, as is the case for this performance measure, are not as reliable as originally anticipated. We therefore have not relied on the model output for this performance measure, and recommend that this approach be changed so that it uses indicator regions identified by the Restudy. If this change is made, we are willing to work with your staff and that of the South Florida Water Management District to identify a suitable suite of indicator regions in the WCAs. We note that it would be desirable to change the stage duration curves and hydrographs, which are also based on output for single grid cells, to reflect this better understanding of the strengths and weaknesses of the model. If this change is not made, then we can only use this performance measure as a very crude indicator of trend among models.

Finally, our 20 May 1998 Planning Aid Letter mentioned a concern as to whether implementation of WSE would cause water-quality problems in the interim before the Stormwater Treatment Areas mandated by the Everglades Forever Act in 1994 came on line. According to the model output that displays the number of flood-control releases from the lake, WSE would send 220% as much water into the WCAs as would Run 25 under 1990 conditions and 140% under 2010 conditions. Run 22AZE would be even more problematic in terms of phosphorus loading by sending 260% and 270%, respectively. Accordingly, the SFWMD has analyzed the potential impacts of implementing WSE versus Run 25 in the WCAs in terms of increased acres of cattails and increased acres of water with a phosphorus concentration above 10 ppb (the fall-back criterion of the Everglades Forever Act, and an approximate concentration where changes in the periphyton community are seen), assuming phosphorus concentrations of 70 ppb and 100 ppb, as measured at the inflow structures to the WCAs. Although this analysis determines that only 3 to 5% of the phosphorus load comes from the lake (the rest coming from the Everglades Agricultural Area), the difference between acres affected by Run 25 versus WSE can be assumed to be due to the schedules themselves.

Water Conservation Area-1 (A.R.M. Loxahatchee National Wildlife Refuge) is the only WCA predicted to have a decreased phosphorus loading under WSE, resulting in a decline of 52 acres of cattails and a decline of 1,087 acres of water with a phosphorus concentration over 10 ppb, given concentrations of either 70 ppb and 100 ppb through S-5A and S-6. (As it turned out, the difference in the two phosphorus concentrations at the inflow structures did not result in a difference in acreage of impact.) This effect is due to a decrease in discharges from the lake to WCA-1 under WSE. On the other hand, WSE would result in an increase of cattails in WCA-2A by 31 acres, presumably in addition to the existing expanding area of cattails south of the S-10 structures; and cause a 790-acre area to have phosphorus concentrations over 10 ppb. Water Conservation Area-3A does not fare much better, with a predicted increase in cattails of 13 acres, presumably in addition to an existing large area of cattails that has developed north of Alligator Alley (I-75) during the past decade; and result in a 2,134-acre area with phosphorus concentrations over 10 ppb.

It is not clear whether these results should be interpreted as meaning that, for example, WCA-3A would experience a 2,147-acre impact (13 acres of cattails + 2,134 acres) of higher than desirable concentrations of phosphorus, or whether the 13 acres of cattails is a subset of the acreage with phosphorus concentrations over 10 ppb. Presumably, these figures represent the number of acres in addition to the impacts that have already occurred in the WCAs. We are extremely uneasy with the idea of allowing more impacts to two WCAs that have already suffered from water-quality impacts and cattail expansion. Not only have cattails invaded the northern part of WCA-2A, but their distribution has also greatly expanded in northeastern WCA-3A since the early 1990s (T. Towles, GFC, pers. comm.). The cause of this phenomenon is not clear, but it may be a combination of deeper water from the recent series of wet years in areas where muck has burned in the past and poor-quality water spreading into WCA-3A from the Miami Canal. In any case, although we are pleased to see that conditions in WCA-1 would actually be improved through the implementation of WSE, we are concerned that this improvement appears to come at the expense of the other WCAs.

<u>Everglades National Park.</u> The performance measures for impacts of the alternatives for Everglades National Park were limited to stage hydrographs and stage duration curves for selected cells (i.e., ones with gages) within the South Florida Water Management Model, mean Natural System Model hydroperiod matches for the park over the 31-year period of record, and various computations of average annual overland flow. We did not review the results of the hydrographs and duration curves for the same reason that we did not do so for the WCAs. Furthermore, the U.S. Geological Survey review of the Natural System Model also pointed out that one of the least reliable forms of model output is overland flow, and that all forms of predictions are least reliable at the model boundaries. For these reasons, we conclude that the model output for Everglades National Park may be too crude to use to detect differences in regulation schedules in Lake Okeechobee.

**Recommendations**

From the information that we have been able to compare, it is not clear whether Run 22AZE or WSE is preferable as a replacement for Run 25; therefore, we defer our recommendation as to which schedule should be supported until we can review the information that will be presented in the draft Environmental Impact Statement (EIS). We do, however, offer the following recommendations for issues to be included in the EIS.

1. We assume that questions we have raised and information we have requested in our two Planning Aid Letters will be provided by the draft EIS that is under development. One exception is our request to include the climate-forecasting capability of HSM and WSE to Run 22AZE and COE, since it has been explained by SFWMD staff why such an effort would not be possible. If the outstanding issues have not been incorporated into that draft report, then we strongly recommend that the graphic representations (including an enlarged version of the daily stage hydrograph for Lake Okeechobee with the "wading bird windows" clearly marked) requested be included and that our questions be addressed, either through the draft EIS itself or under separate cover to us by the time that the draft EIS is released.

2. Model output for performance measures that are based on individual grid cells in the WCAs should be based instead on selected indicator regions, as identified by the Restudy. If this is not feasible, then we recommend that the EIS indicate the degree of precision with which one may interpret the output for these performance measures.

3. The draft EIS should contain a section that clearly lays out the rationale for decreasing the amount of water, and therefore the phosphorus load, that WCA-1 would receive under WSE, while increasing it to the other WCAs. This rationale should be sufficiently compelling to override the damage that is predicted to occur in WCAs-2A and -3A.

4. Should WSE be implemented, we very strongly recommend that a standing, interagency team of biologists be formed to consult with the U.S. Army Corps of Engineers and SFWMD to interpret the operational guidelines [e.g., the references in Zone A(ii) to "reasonable time frame," in Zone B(iv) to "prolonged periods," in Zone C(iii) to "when necessary to minimize impacts to coastal estuaries," and in Zone D to "when necessary to minimize impacts to coastal estuaries"]. This recommendation is consistent with and provides further guidance on the footnote to the

WSE schedule that "consultation with Everglades and estuarine biologists is encouraged to minimize adverse effects to downstream ecosystems."

Sincerely,

Bradley J. Hartman, Director
Office of Environmental Services

BJH/MAP
ENV 2-18/5
LOCAR1.LET
Attachment
cc: Mr. Stephen Forsythe, FWS, Vero Beach
Mr. James Harvey, SFWMD, West Palm Beach
Mr. Robert Pace, FWS, Vero Beach
Dr. Barry Rosen, SFWMD, West Palm Beach
Mr. Mark Ziminske, COE, Jacksonville

**Reports reviewed for this FWCA report**

Anonymous. 1999. *Phosphorus Issues Associated with the Lake Okeechobee Regulation Schedule*, draft white paper dated 12 March 1999. South Florida Water Management District, West Palm Beach. 10 pages.

Neidrauer, C., P. J. Trimble, and E. R. Santee. 1998. *Simulation of Alternative Operational Schedules for Lake Okeechobee*, final report dated 7 May 1998. Hydrologic Systems Modeling Division, Planning Department, South Florida Water Management District, West Palm Beach. 6 sections, paginated independently.

Operational Planning Core Team. 1999. *Implementation Strategies towards the Most Efficient Water Management: The Lake Okeechobee WSE Operational Guidelines*, final draft report dated 9 February 1999. Jointly produced by South Florida Water Management District, West palm Beach, and U.S. Army Corps of Engineers, Jacksonville. Unpaginated + 7 unpaginated appendices.

Trimble, P.J., E. R. Santee, and C. J. Neidrauer. 1998. *Special Report: A Refined Approach to Lake Okeechobee Water Management: An Application of Climate Forecasts*, dated June 1998. Hydrologic Systems Modeling Division, Planning Department, South Florida Water Management, West Palm Beach. 57 pages + 5 appendices, paginated separately.

**Model Output Reviewed**

Total Flood Control Releases from Lake Okeechobee for 31 Years
Number of Undesirable Lake Okeechobee Stage Events
Number of Times Salinity Envelope Criteria Were NOT Met: St. Lucie Estuary
Number of Times High Discharge Criteria (over 1600 and 2500 cfs) Were Exceeded: St. Lucie Estuary
Number of Times Salinity Envelope Criteria Were NOT Met: Caloosahatchee Estuary
Number of Times High Discharge Criteria (over 2800 and 4500 cfs) Were Exceeded: Caloosahatchee Estuary
Percent of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 2-17
Number of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 2-17
Percent of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 3A-3
Number of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 3A-3
Percent of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 3A-28

Number of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 3A-28

Percent of Times Marsh Stage is Lower than 1 Foot below Ground for More than 30 Days: Gage 3A-2

# ANNEX B

# COASTAL ZONE CONSISTENCY EVALUATION

## Florida Coastal Zone Management Program
## Federal Consistency Evaluation Procedures

### Lake Okeechobee Regulation Schedule Study

1. Chapter 161, Beach and Shore Preservation.

The intent of the coastal construction permit program established by this chapter is to regulate construction projects located seaward of the line of mean high water and which might have an effect on natural shoreline processes.

Response: The proposed work project is not seaward of the mean high water line and would not affect shorelines or shoreline processes.

2. Chapters 186 and 187, State and Regional Planning.

These chapters establish the State Comprehensive Plan which sets goals that articulate a strategic vision of the State's future. It's purpose is to define in a broad sense, goals, and policies that provide decision-makers directions for the future and provide long-range guidance for an orderly social, economic and physical growth.

Response: The proposed work has been coordinated with the State without objection. The draft EIS will be coordinated with the State to determine final compliance.

3. Chapter 252, Disaster Preparation, Response and Mitigation.

This chapter creates a state emergency management agency, with the authority to provide for the common defense; to protect the public peace, health and safety; and to preserve the lives and property of the people of Florida.

Response: The proposed project purpose will have no adverse effect on existing or projected future flood control, or public safety. Adequate flood control for residents of the region will be maintained. Public health may be enhanced through improved lake and estuarine water quality and concomitant improvements to the health of fish and wildlife resources and individuals or communities using these natural resources. No action may result in conditions which enhance the possibility of a project failure, resulting in an emergency situation and potentially causing significant damage to persons and property. Therefore, this work would be consistent with the efforts of Division of Emergency Management.

4. Chapter 253, State Lands.

This chapter governs the management of submerged state lands and resources within state lands. This includes archeological and historical resources; water resources; fish and wildlife resources; beaches and dunes; submerged grass beds and other benthic communities; swamps, marshes and other wetlands; mineral resources; unique natural features; submerged lands; spoil islands; and artificial reefs.

Response: The study purpose is to identify and implement a lake operational schedule which will optimize benefits to the natural environment, including the Lake Okeechobee littoral zone and marsh, the downstream estuaries, and the Everglades, with little or no adverse impact to existing project purposes. The WSE regulation schedule has demonstrated distinct ecological benefits for the lake littoral zone and marsh, some positive benefits for the St. Lucie Estuary, including benthic communities, seagrasses etc., and limited benefits to Everglades hydroperiods in the northern areas of WCA 3A and WCA 2A. The proposed project appears to be a sound compromise between benefiting important ecological resources to the north, directing more flows southward through the natural system as opposed to losing this water to tide, while incurring minor, localized water quality impacts and cattail expansion in northern WCA 3A and WCA 2A.

5. Chapters 253, 259, 260, and 375, Land Acquisition.

This chapter authorizes the state to acquire land to protect environmentally sensitive areas.

Response: The proposed action is completely operational, and no structural features, construction, modification of existing structures, or land acquisition is being proposed. Therefore, this study is in compliance with this chapter.

6. Chapter 258, State Parks and Aquatic Preserves.

This chapter authorizes the state to manage state parks and preserves. Consistency with this statute would include consideration of projects that would directly or indirectly adversely impact park property, natural resources, park programs, management or operations.

Response: As stated in #5, above, the proposed action requires no construction work of any kind, land acquisition, or modification of existing structures. It would not affect any state parks or preserves, and would, therefore, be consistent with this chapter.

7. Chapter 267, Historic Preservation.

This chapter establishes the procedures for implementing the Florida Historic Resources

Act responsibilities.

Response: The study is in partial compliance at this stage. Consultation with the Florida State Historic Preservation Officer (SHPO) has been initiated. Historic preservation compliance will be completed to meet all responsibilities under Chapter 267.

8. Chapter 288, Economic Development and Tourism

This chapter directs the state to provide guidance and promotion of beneficial development through encouraging economic diversification and promoting tourism.

Response: Contribution from the study area to the State's tourism economy would not be compromised by project implementation. The project would be compatible with tourism for this area and could potentially contribute to overall growth, development and sustainability of the area through greater protection and enhancement of key natural resources, including freshwater and estuarine fisheries and wildlife. Therefore, the proposed action would be consistent with the goals of this chapter.

9. Chapters 334 and 339, Public Transportation.

This chapter authorizes the planning and development of a safe balanced and efficient transportation system.

Response: The proposed project would not impact the existing public transportation system of the area and therefore, would be consistent with the goals of this chapter.

10. Chapter 370, Saltwater Living Resources.

This chapter directs the state to preserve, manage and protect the marine, crustacean, shell and anadromous fishery resources in state waters; to protect and enhance the marine and estuarine environment; to regulate fishermen and vessels of the state engaged in the taking of such resources within or without state waters; to issue licenses for the taking and processing products of fisheries; to secure and maintain statistical records of the catch of each such species; and, to conduct scientific, economic, and other studies and research.

Response: The proposed action will in fact enhance conditions in the St. Lucie Estuary through reduced high volume regulatory discharges from Lake Okeechobee, contributing to better estuarine water quality and salinity regimes. The proposed action will not adversely impact the Caloosahatchee River Estuary. The marine, estuarine, crustacean, shell and anadromous fishery is expected to benefit from implementation of the WSE regulation schedule. The proposed project is therefore in compliance with chapter 370.

12. Chapter 372, Living Land and Freshwater Resources.

This chapter establishes the Game and Fresh Water Fish Commission and directs it to manage freshwater aquatic life and wild animal life and their habitat to perpetuate a diversity of species with densities and distributions which provide sustained ecological, recreational, scientific, educational, aesthetic, and economic benefits.

Response: The proposed project has been coordinated with the Florida Game and Fresh Water Fish Commission (GFC) without objection. The GFC has prepared a Fish and Wildlife Coordination Act Report (CAR), dated April 16, 1999 (***Annex B***). The Corps has agreed to comply with the recommendations contained in the CAR and outlined in section 9.2.2 of the draft EIS. Therefore, the work would comply with the goals of this chapter.

13. Chapter 373, Water Resources.

This chapter provides the authority to regulate the withdrawal, diversion, storage, and consumption of water.

Response: The proposed project does not involve the transportation or discharge of pollutants. The study is an operations only adjustment of existing protocols for managing Lake Okeechobee water levels, and regulatory discharges downstream as they are currently conducted.

14. Chapter 376, Pollutant Spill Prevention and Control.

This chapter regulates the transfer, storage, and transportation of pollutants and the cleanup of pollutant discharges.

Response: As stated in #13, above, this work does not involve the transportation or discharging of pollutants. Therefore, the chapter is not applicable to the proposed action.

15. Chapter 377, Oil and Gas Exploration and Production.

This chapter authorizes the regulation of all phases of exploration, drilling, and production of oil, gas, and other petroleum products.

Response: This proposed action does not involve the exploration, drilling or production of gas, oil or petroleum product and therefore does not apply.

16. Chapter 380, Environmental Land and Water Management.

This chapter establishes criteria and procedures to assure that local land development decisions include consideration of the regional impacts of proposed large-scale development.

Response: The proposed action does not involve land development as described by this chapter therefore, this chapter is not applicable.

17. Chapter 388, Arthropod Control.

This chapter provides for a comprehensive approach for abatement or suppression of mosquitoes and other pest arthropods within the state.

Response: The proposed action would not further the propagation of mosquitoes or other pest arthropods.

18. Chapter 403, Environmental Control.

This chapter authorizes the regulation of pollution of the air and waters of the state by the Florida Department of Environmental Protection.

Response: A Draft Environmental Impact Statement has been prepared and will be reviewed by the appropriate resource agencies including the Florida Department of Environmental Protection.

19. Chapter 582, Soil and Water Conservation.

This chapter establishes policy for the conservation of the state soil and water through the Department of Agriculture. Land use policies will be evaluated in terms of their tendency to cause or contribute to soil erosion or to conserve, develop, and utilize soil and water resources both onsite or in adjoining properties affected by the work. Particular attention will be given to work on or near agricultural lands.

Response: The affected area includes agricultural lands, however no adverse impacts to existing water supply or flood control for agricultural lands within the study region are predicted. The proposed action, as mentioned above, is completely operational in nature and does not involve the disturbance of surface or sub-surface soils in any way. Soil erosion problems will not be exacerbated due to implementation of the proposed action. Possible, minor benefits may be accrued along the St. Lucie Canal through a slight reduction in canal bank erosion due to reduced flows to the St. Lucie Estuary.